THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

Final Report

by

Monenco Consultants Limited

September, 1986

Work on this project was conducted under the auspices of the Department of Energy, Mines and Resources

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THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

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Mr. V. Srajer
Surface Mining Research Laboratory
CANMET
One Oil Patch Drive
P.O. Bag 1280
Devon, Alberta
TOC 1E0

Dear Mr. Srajer:

Re: The Assessment, Evaluation and Validation of a Computer-Based Simulation Model DSS File No. 03SQ.23440-5-9249

We are pleased to present our final report for the above project, in twenty bound copies each of which includes an executive summary in English and French.

Part 1 provides the background to the study; Part 2 deals with the examination of the documentation; Part 3 presents the results of experiments performed using default data; Part 4 contains the results of experiments performed using actual test examples. Part 5 indicates our overall impressions of the software plus our conclusions and recommendations.

We have included in the Appendices the results of the 47 experiments that we performed during the course of the study.

We have found the work on the project extremely interesting and trust that the report will be to your satisfaction. We shall be pleased to answer any questions arising from the report.

Yours very truly,

H Michael Wise

H. MICHAEL WISE

H.M. Wise, P.Eng.
Project Manager

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Vice-President, Mining

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This report was commissioned by the Surface Mining Research Laboratory, CANMET, Devon, Alberta. Its object was to assess, evaluate and validate a computer-based simulation model of a bucket wheel excavator-conveyor-bin/hopper mining system. The simulator had been developed for the CANSTAR oil sands mining project, but software development was terminated abruptly when the CANSTAR project was cancelled. The software was apparently complete and ready for use, but had not been fully evaluated.

The evaluation of the software was to address:

(1) a critical appraisal of the software documentation with regard to validity, completeness and adequacy of the underlying program logic and mathematical relationships, simplifying assumptions, command linkages, input requirements and output respects;

(2) observations made while operating the simulator using default data provided by CANMET; and

(3) observations made while preparing the data and operating the simulator using actual data from case studies provided by CANSTAR and TransAlta Utilities Limited.

Subsequent to contract award, the CANSTAR project was abandoned, and the remaining mining team disbanded. The CANSTAR case study was removed from the project requirement. It was also found during the course of the study that the software was much less developed than CANMET or Monenco had been led to believe. Emphasis in the study shifted to documentation of the difficulties that were encountered.

1.1 POTENTIAL NEEDS OF INDUSTRY

The Canadian mining industry has a need for software that will improve the decision-making of mine operators with regard to equipment selection or changes in operating method. Several mines have recently changed to equipment that incorporates conveyors, and many more are evaluating conveyors as replacements for trucks or locomotives. A conveyor simulator is therefore the most needed software.

There is only one Canadian mine that uses a bucket wheel excavator for mining in-situ overburden, and another Canadian mine that is investigating use of a BWE. Installation at this second mine would occur in the mid-1990's.

2.0 EXAMINATION OF SOFTWARE DOCUMENTATION

The documentation that supports the BWE, conveyor and bin/hopper modules consists of:

LTR-CS-227	An Interactive Simulation Model of Conveyor Systems in Tar Sands Mining - Systems Model Report
LTR-CS-229	An Interactive Simulation Model of Conveyor Systems in Tar Sands Mining - Computer Model Report
LTR-CS-231	An Interactive Simulation Model of Bin/Hopper Systems in Oil Sands Mining
-	Users Guide - Interactive Model of an Open Pit Mine Bucket Wheel Excavator Model
-	Programmer's Guide - Interactive Model of an Open Pit Mine Bucket Wheel Excavator Model

We found that system logic and mathematical formulae are well-explained in the documentation and generally in order. The terminology was not always clearly explained and did not always coincide with the accepted usage in the mining industry.

The documentation does not have an "In Case of Difficulty" section for any module. Run failures that result in operating system messages can easily occur, and even the program halts that are program-controlled are not described in the documentation.

The BWE module is heavily oriented towards tarsands operation, and particularly the type of operation envisioned for CANSTAR. Examples of this orientation are the concern with material grade, boulder frequency, and layers. This orientation adds a level of complexity to the module that could be removed if the model were used for modelling a waste stripping operation.

The conveyor module and the bin/hopper module have more general applicability. The conveyor module is specific to tensioned belt conveyors.

3.0 OPERATION OF MODELS USING DEFAULT DATA

3.1 CONVEYOR-BIN/HOPPER MODEL

The conveyor-bin/hopper model ran without errors using the default data. The documentation was only moderately adequate as a guide for making subsequent changes to the base data files. One large gap in the documentation was lack of description of the special files that control the master simulation program ANEVNT.

There are two outputs to the program.

The terminal output is visually attractive and contains sufficient information to determine whether the program is proceeding satisfactorily. The printed report has the capability of producing an initialization report that proved very useful, and hourly, shift and day production reports. This information was sufficient to determine that the conveyor module correctly performed its internal calculations.

The conveyor module has been set up with capacity as an input quantity, belt width as an optional input quantity, and belt speed as a calculated quantity. Since the model would be most likely used at operations where belt width and speed are fixed for a particular installation, it would be better to have belt width the required input, belt speed an optional input, and capacity the calculated quantity.

The conveyor was able to correctly calculate the energy requirements of both uphill and downhill grades.

Certain quantities in the output report are formatted too restrictively, so that "output conversion errors" often result. These are minor problems.

3.2 BUCKET WHEEL EXCAVATOR-CONVEYOR-BIN MODEL

The BWE module requires a lot of interactive input that can be confusing to the new user. The documentation is of no assistance for leading the user through this interactive session. As was the case with the conveyor module, the documentation was only moderately adequate to guide making subsequent changes to the base data files. The documentation was written at a time when the BWE module was standalone; subsequent program modification changed both items within data files and the need for certain other files.

The BWE module does not have provision for an hourly production report. Nor is there a debug capability. It proved impossible to determine if the conveyor module was correctly performing its internal calculations. The productivity predicted by the simulator for the default BWE machine while in the bench-digging mode agrees quite closely to rule-of-thumb estimates.

Even when using the default data there was an indication that the BWE module has a problem with overall production volumes. There is a discrepancy between the volume mined according to the count of blocks in the mining sequence versus the volume mined according to the production report. The test cases of the case studies indicated that this is likely due to an index problem.

The computer code that controls the movement of the BWE and conveyors at the "end of a section" has never been written.

The method of handling the interface of the BWE to the mining material is totally inadequate. The BWE simulator makes use of two cumbersome ASCII files: DDBASE.DAT and SEQ.DAT. DDBASE.DAT is a file that contains coordinate and block dimension information and the geological parameters for each block. SEQ.DAT indicates the order in which blocks are mined.

The geology model described in DDBASE.DAT is a 3-dimensional block model. The bench to be mined by the BWE machine is divided into layers, and all layers must be the same thickness. This layer thickness is the block height. The block width corresponds to the width of the mining bench that the BWE will mine in one pass down the length of the pit. The block length is arbitrary, but all blocks in the 3-D model must have the same length. Furthermore, each bench in an operation must have its own block model, although models may be combined into a single DDBASE.DAT. The program will not permit a single BWE to work on more than one bench.

There appears to be no internal checking to see if the BWE is close enough to the conveyor to discharge material onto the belt.

4.0 OPERATION OF MODELS USING TEST EXAMPLES

The sole case study used was Pit 04 at Highvale Mine. This is a large plains thermal coal mine owned by TransAlta Utilities Corporation. Previous studies have shown that prestripping of overburden will be required at Pit 04 after 1995, and that the most cost-effective method overburden removal of the prestrip quantity could be by use of a BWE system. Two consultants have proposed solutions that entail radically different operating methods and very different-sized bucket wheel excavators.

4.1 MONENCO CASE STUDY

Three test cases were developed from the prestripping proposal suggested by Monenco. They represent conditions when the prestrip operation has just begun, in the middle of the pit life, and near the planned end of Pit 04. They represent increasing overburden thicknesses. A large bucket wheel excavator will dig along east-west cuts, feeding an around-the-pit conveyor system.

Preparation of the datafiles used by the BWE, conveyor and bin/hopper modules was straightforward. However, it was found that the formats of the files were much more restrictive than implied in the demonstration. Considerable effort was expended to get the simulator to run. A user who is not a competent FORTRAN programmer would be unlikely to get the simulator working on his own data.

The modules do not have a sufficient number of internal checks for data compatability. Only by examination of the code in an attempt to solve a problem was it found that the BWE module has been dimensioned to a maximum of 120 steps, 2 sections, 5 layers and 10 columns.

There is a restriction built into the BWE program that relates the machine hinge distance to the layer thickness. This restriction is not supported in the literature nor by actual field conditions.

The block model DDBASE.DAT must be established with increasing real co-ordinates along the X-axis, that is along the length of the cut mined by the BWE. This restriction forced redefinition of the entire TransAlta mine grid at Highvale from "northings" and "eastings" to "southings" and "westings".

In several cases, certain input variables are expressed in different units in the documentation and in the echo in PRINT.DAT. Digging resistance was particularly troublesome. The digging resistance of the material in a block is expressed in units kg/cm^2 while cutting resistance has units kg/cm.

The BWE simulator has a problem accounting for volumes. The cause of the problem appears to be an index problem relating to position of the machine within the block model. In Monenco Test Case 3, the block position indicator cycled randomly between columns with the layer index stuck at 3.

Monenco Test Case 3 required that the BWE operate on two separate benches. The program is unable to handle this situation. Nor can the simulator handle a situation where a belt wagon is sometimes used and sometimes not used.

Dr. Chan of NRC developed a code that would allow the BWE to move to a new section. This worked for Monenco Test Case 1, but did not work for Monenco Test Case 3 because no run ever activated the "end of section" event. The index problem seems to be related to the model dimensions, because the main difference between the two models is that one has four layers, and the other has five layers.

4.2 KRUPP CASE STUDIES

Two case studies were developed from the prestripping proposal suggested by Krupp. Two medium-capacity bucket wheel excavators will dig along north-south cuts. The lower machine will feed directly onto a long cross-pit stacker. The upper machine will only be commissioned when required. It will feed a round-the-pit conveyor system. Both machines operate in a complex pattern to minimize conveyor moves and maximize the equipment output capacity. There are test cases for both the Lower System and Upper System case studies.

The Krupp test cases were not modelled using the simulator. The Monenco Test Case 3 had shown that the simulator was incapable of handling a two-bench operating system, while the Krupp Upper System uses 4 benches for the single machine. The movements of the BWE and belt wagon are also much more complex in the Krupp case than in the Monenco case, yet the simulator was not able to simulate even the Monenco situation.

Differences in bench heights between the Krupp propsal and the test cases caused by the required uniform layer thickness also meant that any comparison of results to previous studies would be meaningless.

A box cut method is used in the Krupp case for mining the lowermost bench of the upper system. There is no capability in the BWE simulator for handling this type of operating strategy.

5.0 CONCLUSIONS

5.1 OVERALL IMPRESSIONS

511 UNDERLYING THEORY

The bucket wheel excavator, conveyor and bin/hopper modules have been built with the goal of simulating the operations of the equipment to sufficient accuracy that they could be used for production monitoring. The required accuracy is achieved by modelling the equipment functions at their most detailed level, based upon the empirical formulae published mainly by the Conveyor Equipment Manufacturers Association and L. Rasper. These formulae have been well-proven in practice elsewhere and have been shown to yield reliable results when used within the boundaries of the experience on which they are based.

It is doubtful whether this precision is required when the equipment is used in a full operational environment. For example, it is possible when using Rasper to precisely calculate the length of time required to perform a slice. Yet reverse slew time, positioning time, operational efficiency and times for equipment breakdown are all arbitrary factors that the program user must enter. Cumulatively, the importance of these arbitrary factors on overall productivity is at least as great as the precise calculations that come from the empirical formulae.

Because of these uncertainties, a much simpler BWE model that employed distributions for "time to complete a slice", "reverse slew time" and "tramming time" would provide a result equally reliable to the current method, but with far less computational effort.

As for the conveyor model, for production monitoring the belt width and belt speed are known, and therefore belt capacity is either a known quantity or can be calculated from the CMA formula. The mechanical and electrical availability of simple conveyor networks is so high that for short-term monitoring they can be considered as always available.

A BWE-conveyor-bin operating system is essentially a continuous serial process. Simulation is more commonly used in two other situations: multiple runs through a serial continuous process in order to determine the distribution of possible outcomes, or for studies of queuing on a discrete process. Empirical formulae rather than statistical distributions are used for the parts of the BWE model most appropriate for simulation techniques. Nevertheless, the idea of using the simulation method is attractive if only because it forces the prospective program user to think about the ranges of possible outcomes - for example if a conveyor breaks down, how long it is likely to be unavailable.

512 DOCUMENTATION

Documentation should help the prospective user understand the way a program accomplishes its function, help the user to get the program to work using his own data and help the user when he gets into problems.

All three models that comprise the BWE-conveyor-bin/hopper model have documentation that clearly illustrates the theory that underlies the modules. The overall impression of the documentation with respect to understanding the theory is very favourable.

The modules are less successful when it comes to helping the user to enter his data and get the program running. Two serious deficiencies are apparent. The formats for data files used by the bin/hopper and conveyor modules that are specified in the documentation are implied to be "free format". However, free format input will not work, and data must be entered precisely as shown in the supplied examples with commas separating all variables and at the end of each record, no internal spaces, and decimal points accompanying real-valued variables. There are neither warnings in the documentation nor internal data checks to ensure that the user's data lies within the acceptable limits to the empirical formulae and within the program dimensions.

The documentation does not have an "In Case of Difficulty" section for any module. Run failures that result in operating system messages are all too frequent, and even those program halts that are program-controlled are not described in the documentation.

A user who is not a competent FORTRAN programmer would be unlikely to get the simulator working on his own data.

513 OPERATION

The simulator is difficult to get to work. There are numerous data files to prepare, and the formats of several of the files are less flexible than we would like to see. The BWE module has a useful input echo that the other modules could copy; the bin/hopper and conveyor modules have a useful debug facility that the BWE module could profitably use.

The means of specifying the geology and mining sequence to the simulator is awkward and needs revision. At the extreme, the layer specification dictates the operational method rather than the other way around.

The terminal display is good. The information that is displayed is useful and permits adequate monitoring of the simulation. No changes are required.

The interrupt menus were seldom used. They appear generally adequate, but do not cover the very wide range of operational options that are possible. As one simple example, one cannot change from bench cut to drop cut in the middle of a run, yet if material digging resistance were to change along a bench it may be necessary to make the change. Nor were we able to add or delete the belt wagon in the middle of a run.

Two printouts are available. All movements of the bucket wheel excavator are recorded in FOR021.DAT. This printout is very useful. Status changes in the conveyor network or the bin/hopper are recorded in the main report PRINT.DAT when the appropriate debug switch is activated. The conveyor and bin/hopper status changes need to be output into FOR021.DAT.

PRINT.DAT is the main output report. The initialization echoes are adequate although we would like to see echoes of the conveyor and bin/hopper input data. These are available (although some have been converted) if the appropriate debug switch is activated. A graphical representation of the Weibull distributions would improve the user's confidence that they have been correctly specified.

There is no hourly BWE production report. Nowhere on the report does it indicate the volume of material that has passed through the bin/hopper. Otherwise, the hourly, shift, day and total reports are adequate.

The simulator was unable to handle the relatively simple operational procedure represented by Monenco Test Case 3. It is certainly incapable of handling the more complex Krupp Test Cases. Yet these are not unusual operational methods; the simulator, to be useful, must have far greater operational flexibility than it now possesses.

The bucket wheel module is unable to calculate mined volumes and operating hours correctly. The problem appears to be caused by an internal indexing problem hidden somewhere inside the code.

5.2 SUGGESTIONS FOR IMPROVEMENT

The following changes could be made to make the simulator more useful for overburden mining:

a) Delete all references to lateral cut method of mining;

b) Remove the concept of layers, and introduce a flexible bench height;

c) Delete all references to material grade;

d) Add tripper/spreader capability to conveyor model;

e) Make input files truly free format;

f) Delete all references to more than one piece of feeding equipment;

g) Delete the empirical CEMA and Rasper formulae; make them stand-alone programs useful for equipment sizing studies;

h) Replace Rasper formulae by statistical distributions that the program user can input;

i) Write an "In Case of Difficulty" section to the documentation;

j) Increase debug capabilities of the BWE module; add input echo to conveyor and bin/hopper modules;

k) Improve range of user-variable options available during the course of a simulation;

l) Make conveyors independently moveable, so that the belt wagon and stacker could be modelled as conveyors; and

m) Add capability to handle cable belt and high-angle conveyors.

These changes amount to a virtual re-writing of the entire BWE module, plus significant changes to the conveyor module. It is difficult to estimate how long it would take to make these changes, but as a very rough estimate two man-years could provide a tested product with moderate operational flexibility and user-friendliness.

5.3 CONCLUSIONS

There is a need in the Canadian mining industry for a product similar to the bucket wheel-conveyor-bin/hopper model. The most pressing need is for a product that will assist with equipment selection and selection of improved operating methods.

At present, a conveyor model would receive most use. Specific projects that may require evaluation are direct shovel loading of mobile crushers; permanent in-pit crusher stations; high-angle conveying out of pit; continuous underground mining machinery.

Suncor is the only Canadian mine that currently uses a bucket wheel excavator for mining in-situ overburden. TransAlta is considering the installation of a BWE-conveyor system for overburden removal at the Highvale Mine.

The NRC/CANMET simulator is not yet ready to fulfill this industry requirement.

The development of the BWE-conveyor-bin/hopper simulator was halted abruptly with the cancellation of the Canstar oil sands project in 1982. The simulator shows the effect of this abrupt termination. Certain portions of the code have in fact never been written, and the results that the simulator does achieve are not always correct.

Major revisions to the simulator, and particularly to the BWE module, will be required in order to make the simulator a product that is potentially useful to industry.

A comprehensive search needs to be made in the marketplace for alternative products prior to further investment in the NRC/CANMET simulator.

5.4 RECOMMENDATIONS

As presently constituted, the BWE-conveyor-bin/hopper simulator is not ready for use by Canadian industry. Considerable modification, especially to the BWE module, would be required in order for the simulator to be even partially effective for the short-term production monitoring that it has been designed to do.

Prior to making this investment, we recommend that CANMET conduct a worldwide survey to determine what products are currently available in the market that claim to satisfy either the short-range or longer-range needs of Canadian industry. If products are found, we recommend that they be evaluated against a pre-determined set of requirements, then the highest-ranking programs should be evaluated in a similar manner as the NRC-CANMET simulator.

We can recomend further investment in the NRC-CANMET simulator only if an exhaustive search of the world marketplace does not uncover a satisfactory alternative for short-range production monitoring. In that case there may be an advantage in rewriting the BWE module of the simulator rather than try to upgrade it.

RÉSUMÉ

1.0 INTRODUCTION

Le présent rapport a été commandé par le Laboratoire de recherche sur l'extraction à ciel ouvert, de CANMET, à Devon (Alberta). L'étude visait à examiner, évaluer et valider un programme informatisé de simulation d'un système d'exploitation minière comprenant un excavateur à godets, des convoyeurs et des trémies. Le simulateur a été conçu dans le cadre du projet CANSTAR d'exploitation des sables bitumineux, mais la réalisation du logiciel a été brusquement interrompue par l'annulation du projet. Le logiciel était apparemment complet et prêt à être employé, mais il n'avait pas encore fait l'objet d'une évaluation exhaustive.

L'évaluation du logiciel devait comprendre les points suivants :

(1) une analyse critique de la documentation qui accompagne le logiciel et qui devait porter sur plusieurs facteurs : validité, exhaustivité et pertinence des relations mathématiques et logiques sous-jacentes au programme, hypothèses de simplification, liens de commande, exigences d'entrées et rapports de sortie;

(2) des observations sur le fonctionnement du simulateur à l'aide de données implicites fournies par CANMET; et

(3) des observations sur la préparation des données et le fonctionnement du simulateur à l'aide de données réelles provenant d'études de cas fournies par CANSTAR et TransAlta Utilities Limited.

Après l'adjudication du contrat, le projet CANSTAR a été abandonné et le reste de l'équipe d'exploitation minière a été démembré. L'étude de cas CANSTAR a donc été rayée des exigences de l'étude. Au cours de l'étude, on s'est également rendu compte que le logiciel était beaucoup moins développé que CANSTAR ou Monenco l'avait cru initialement. En définitive, l'étude a principalement porté sur l'analyse des difficultés qui ont été rencontrées.

1.1. BESOINS POTENTIELS DE L'INDUSTRIE

L'industrie minière canadienne a besoin de logiciels qui permettront d'améliorer les décisions prises par les exploitants miniers au sujet du choix du matériel ou des modifications des méthodes d'exploitation. Plusieurs mines ont récemment modifié leur matériel et emploient maintenant des convoyeurs; en outre, de nombreuses mines étudient la possibilité d'employer des convoyeurs au lieu des camions et des locomotives. L'industrie a donc besoin d'un simulateur de convoyeur.

Il n'existe qu'une seule mine au Canada qui utilise un excavateur à godets (EG) pour l'enlèvement des morts-terrains de recouvrement; une autre mine envisage actuellement la possibilité d'utiliser un EG. Dans ce dernier cas, l'EG serait installé vers le milieu des années 1990.

2.0 EXAMEN DE LA DOCUMENTATION DU LOGICIEL

La documentation qui accompagne les modules EG, convoyeur et trémie comprend ce qui suit :

LTR-CS-227	Modèle de simulation interactive des réseaux de convoyeurs dans une exploitation de sables bitumineux - Rapport sur le modèle des réseaux.
LTR-CS-229	Modèle de simulation interactive des réseaux de convoyeurs dans une exploitation de sables bitumineux - Rapport sur le modèle informatisé.
LTR-CS-231	Modèle de simulation interactive des systèmes de trémies dans une exploitation de sables bitumineux.
-	Guide de l'utilisateur - Modèle interactif d'un excavateur à godets dans une mine à ciel ouvert.
-	Guide du programmeur - Modèle interactif d'un excavateur à godets dans une mine à ciel ouvert.

Nous avons trouvé que les relations logiques du système et les formules mathématiques sont bien expliquées dans les documents et qu'elles suivent un ordre cohérent. Toutefois, la terminologie n'est pas toujours clairement expliquée et ne correspond pas toujours à l'usage accepté dans l'industrie minière.

Les documents ne comportent pas de section "En cas de difficultés". Les incidents d'exécution qui provoquent l'affichage de messages du système d'exploitation peuvent se produire aisément. En outre, la documentation ne décrit même pas les arrêts commandés par le programme.

Le module EG est avant tout axé vers l'exploitation des sables bitumineux, et particulièrement vers le type d'opérations qui étaient envisagées par CANSTAR. Ainsi, le module tient compte de la teneur des matériaux, de la fréquence des blocs et des couches. Cette orientation ajoute au programme un niveau de complexité qui pourrait être retiré si le modèle devait servir à modéliser l'enlèvement des stériles.

Le module convoyeur et le module trémie sont d'une applicabilité plus générale. Le module convoyeur a été conçu particulièrement pour les convoyeurs à courroies tendues.

3.0 FONCTIONNEMENT DU MODÈLE À L'AIDE DE DONNÉES IMPLICITES

3.1 MODÈLE CONVOYEUR-TRÉMIE

Le modèle convoyeur-trémie a fonctionné sans erreur à l'aide des données implicites. La documentation a fourni une aide tout juste suffisante pour les modifications subséquentes des fichiers de la base de données. La documentation comportait une lacune importante en ce qu'elle ne décrivait pas les fichiers spéciaux qui commandent ANEVNT, le programme principal de simulation.

Le programme produit deux sorties.

La sortie au terminal est d'aspect agréable et contient suffisamment d'informations pour permettre à l'utilisateur de savoir si le programme se déroule de façon satisfaisante. L'imprimé comporte un rapport d'initialisation fort utile, ainsi que des rapports de production par heure, quart de travail et jour. Les informations permettant de savoir si le module convoyeur exécutait correctement ses calculs internes étaient suffisantes.

Dans le module convoyeur, la capacité constitue le paramètre d'entrée et la largeur de la courroie, un paramètre d'entrée facultatif. La vitesse de la courroie est la quantité calculée. Étant donné que le modèle serait probablement employé pour des opérations dans lesquelles la largeur et la vitesse de la courroie seraient fixes, il serait préférable que la largeur soit le paramètre d'entrée, que la vitesse soit le paramètre d'entrée facultatif et que la capacité soit la quantité calculée.

Le module convoyeur a été en mesure de calculer correctement les besoins en énergie pour les pentes montantes et descendantes.

Dans le rapport de sortie, certaines quantités sont structurées de façon trop restrictive, de sorte qu'il se produit souvent des "erreurs de conversion à la sortie". Mais il s'agit là d'un problème mineur.

3.2 MODÈLE EXCAVATEUR-CONVOYEUR-TRÉMIE

Le module EG demande beaucoup de travail d'entrée interactif, ce qui peut être source de confusion pour l'utilisateur novice. La documentation n'aide nullement l'utilisateur au cours de cette séance interactive. Comme dans le cas du module convoyeur, la documentation offre une aide tout juste suffisante pour les modifications subséquentes des fichiers de la base de données. La documentation a été rédigée au moment où le module EG était autonome; les modifications subséquentes du programme ont changé le contenu des fichiers de données et la nécessité d'avoir certains autres fichiers.

Le module EG ne prévoit pas l'impression de rapports sur la production horaire. Il ne possède pas non plus de fonctions de mise au point. Il nous a été impossible de déterminer si le module convoyeur exécutait correctement ses calculs internes. La productivité calculée par le simulateur à l'aide de données implicites, pour la machine EG en mode d'excavation par gradins, est très près des estimations obtenues par des méthodes pratiques.

Même avec les données implicites, il semble que le module EG éprouve des difficultés avec les volumes totaux de production. Nous avons en effet noté un écart entre, d'une part, les volumes abattus calculés d'après le nombre de blocs dans la séquence d'exploitation et, d'autre part, les volumes abattus selon le rapport de production. Les passages réalisés avec les données provenant des études de cas laissent entendre que cet écart est probablement attribuable à un problème d'indice.

Le code machine qui commande les mouvements de l'EG et des convoyeurs en "section finale" n'a jamais été rédigé.

L'interface EG-matériaux à excaver est traitée de façon totalement inadéquate. Le simulateur EG fait appel à deux fichiers ASCII encombrants : DDBASE.DAT et SEQ.DAT. DDBASE.DAT est un fichier qui contient des informations sur les coordonnées et les dimensions des blocs, ainsi que les paramètres géologiques de chaque bloc. SEQ.DAT indique l'ordre dans lequel les blocs sont abattus.

Le modèle géologique décrit dans DDBASE.DAT est un modèle de blocs tridimensionnels. Le gradin que doit attaquer l'EG est divisé en couches, et toutes les couches doivent avoir la même épaisseur. Cette épaisseur de couche est la hauteur du bloc. La largeur du bloc correspond à la largeur qu'excavera l'EG dans le gradin en un passage sur toute la longueur du terrain exploité. La longueur d'un bloc est arbitraire, mais tous les blocs doivent avoir la même longueur dans le modèle tridimensionnel. En outre, chaque gradin de l'exploitation doit avoir son propre modèle de blocs, bien que tous ces modèles puissent être combinés en un seul fichier DDBASE.DAT. Le programme n'autorisera pas un EG à travailler sur plus d'un gradin.

Le programme ne semble pas posséder de sous-programme interne dont le rôle serait de vérifier si l'EG est suffisamment près du convoyeur pour décharger les matériaux abattus sur la courroie.

4.0 FONCTIONNEMENT DES MODÈLES À L'AIDE DE DONNÉES PROVENANT D'ÉTUDES DE CAS

Nous avons employé les données provenant d'une seule étude de cas, soit celle du terrain 04 de la mine Highvale, mine de grandes dimensions renfermant du charbon de chaudière. Elle est exploitée par TransAlta Utilities Corporation. Les études précédentes ont démontré qu'il faudra procéder, sur le terrain 04, à l'enlèvement préalable des morts-terrains de recouvrement après 1995 et que la façon la plus rentable d'y parvenir consisterait à employer un système EG. Deux experts-conseils ont proposé des modes d'exploitation complètement distincts faisant appel à des excavateurs à godets de dimensions très différentes.

4.1 ÉTUDE DE CAS RÉALISÉE PAR MONENCO

Trois études d'essai ont été réalisées à partir de la proposition de pré-enlèvement suggérée par Monenco. Elles représentent les conditions suivantes : l'opération de pré-enlèvement vient à peine de débuter, alors que le terrain est rendu à sa demi-vie d'exploitation, et elle est réalisée près de l'extrémité prévue du terrain 04. En outre, les morts-terrains sont plus épais. Un excavateur à godets de grandes dimensions travaillera en abattages est-ouest et alimentera un réseau périphérique de convoyeurs.

La préparation des fichiers de données utilisés par les modules EG, convoyeur et trémie n'a posé aucun problème. Toutefois, nous avons constaté que les formats des fichiers étaient beaucoup plus restrictifs que ce que la démonstration avait laissé entrevoir. Il a donc fallu dépenser des efforts considérables pour que le simulateur puisse fonctionner. Un utilisateur qui n'est pas programmeur FORTRAN accompli aurait probablement de la difficulté à faire fonctionner le simulateur à l'aide de ses propres données.

Les modules ne possèdent pas un nombre suffisant de fonctions internes visant à vérifier la compatibilité des données. Ce n'est qu'en examinant le code afin de solutionner un problème que l'on a constaté que le module EG avait été dimensionné pour un maximum de 120 étapes, 2 sections, 5 couches et 10 colonnes.

En outre, le programme EG comporte une restriction à l'effet que la distance d'articulation de la machine est reliée à l'épaisseur de la couche. Cette restriction n'est étayée par aucune condition réelle sur le terrain, ni par la documentation sur le sujet.

Afin d'établir le modèle des blocs, DDBASE.DAT, il faut augmenter les coordonnées réelles le long de l'axe X, c'est-à-dire le long du chemin d'abattage parcouru par l'EG. Cette restriction nous a obligé de redéfinir toute la grille d'excavation établie par TransAlta pour la mine Highvale, en changeant les directions "nord" et "est" en directions "sud" et "ouest".

Dans plusieurs cas, certaines variables d'entrée sont exprimées en unités différentes dans la documentation; dans l'écho du fichier PRINT.DAT, la résistance à l'excavation a posé un sérieux problème. En effet, la résistance à l'excavation exercée par des matériaux dans un bloc est exprimée en kg/cm^2, alors que la résistance à l'abattage est exprimée en kg/cm.

Le simulateur EG présente un problème de comptabilisation des volumes, lequel semble être attribuable à un problème d'indice lié à l'emplacement de la machine dans le modèle des blocs. Dans l'étude d'essai n^o 3 réalisée par Monenco, l'indicateur d'emplacement de bloc a parcouru de façon aléatoire les colonnes, alors que l'indice de couche était figé à 3.

Selon l'étude d'essai n^o 3 de Monenco, l'EG devrait travailler sur deux gradins séparés. Le programme est incapable de tenir compte d'une telle situation. Le simulateur ne peut également tenir compte d'une situation dans laquelle on a occasionnellement recours à un wagon sur courroie.

Le D^{r} Chan, du CNRC, a conçu un code qui permettrait à l'EG de se déplacer dans une nouvelle section. Ce code a fonctionné pour l'étude de cas n^{o} 1 de Monenco, mais non pour l'étude de cas n^{o} 3, car aucun passage n'a été déclenché par l'événement "fin de section". Le problème d'indice semble lié aux dimensions du modèle, la différence principale entre les deux modèles étant que l'un utilise quatre couches et l'autre cinq couches.

4.2 ÉTUDES DE CAS RÉALISÉES PAR KRUPP

Deux études de cas ont été élaborées à partir de la proposition de pré-enlèvement des morts-terrains faite par Krupp. Deux excavateurs à godets, de dimensions moyennes, travailleront en direction nord-sud. La machine située en aval alimentera directement un long empileur transversal, alors que la seconde machine placée en amont ne sera mise en service qu'au besoin. Cette dernière alimentera un réseau périphérique de convoyeurs. Les deux machines travailleront selon un schéma complexe visant à minimiser les déplacements de convoyeur et à maximiser la capacité de production du matériel. Des études de cas ont été réalisées pour les systèmes aval et amont.

Les études de cas de Krupp n'ont pas été modélisées à l'aide du simulateur. L'étude de cas n^{o} 3 de Monenco a démontré que le simulateur était incapable de prendre en considération un mode d'exploitation sur deux gradins, alors que Krupp prévoit, pour le système amont, l'exploitation de quatre gradins par une seule machine. Les mouvements de l'EG et du wagon à courroie sont beaucoup plus complexes dans la proposition de Krupp que dans celle de Monenco, et le simulateur n'a même pas été en mesure de simuler celle de Monenco.

Dans la proposition de Krupp, les hauteurs des gradins diffèrent de celles des études d'essais. Compte tenu de l'exigence selon laquelle les couches doivent être d'épaisseur uniforme, toute comparaison des résultats des études précédentes n'a donc aucune signification.

Krupp a proposé une méthode d'abattage rectangulaire pour l'exploitation du gradin le plus bas du système amont. Le simulateur EG n'est pas en mesure de tenir compte d'un tel mode d'exploitation.

5.0 CONCLUSIONS

5.1 IMPRESSIONS GÉNÉRALES

511 THÉORIE SOUS-JACENTE

Les modules excavateur, convoyeur et trémie ont été conçus dans le but de simuler le fonctionnement du matériel de manière assez précise de façon à pouvoir les utiliser pour le contrôle de la production. Afin d'obtenir un tel degré de précision, les fonctions du matériel sont modélisées jusque dans leurs moindres détails. La modélisation est fondée sur les formules empiriques publiées principalement par la Conveyor Equipment Manufacturers Association et L. Rasper. Ces formules, bien éprouvées, donnent des résultats fiables lorsqu'elles sont employées à l'intérieur des limites dont on a tenu compte lors de leur formulation.

On peut toutefois se demander si une telle précision est nécessaire pour un matériel utilisé dans un milieu totalement opérationnel. Par exemple, en utilisant les formules de Rasper, on peut calculer précisément le temps nécessaire pour l'abattage d'une tranche. Par ailleurs, le temps de pivotement arrière, le temps de placement, l'efficacité opérationnelle et les temps morts dus aux pannes de matériel sont tous des facteurs arbitraires que l'utilisateur du programme doit introduire dans l'ordinateur. Pris ensemble, ces facteurs arbitraires influent sur la productivité globale au moins autant que les calculs précis réalisés à l'aide des formules empiriques.

Compte tenu de ces incertitudes, un modèle EG beaucoup plus simple, qui aurait recours aux "temps d'abattage d'une tranche", "temps de pivotement arrière" et "temps de roulage", donnerait des résultats aussi fiables que la méthode actuelle, avec des exigences de calcul nettement inférieures.

En ce qui concerne le modèle de convoyeur, le contrôle de la production présuppose que l'on connaît la largeur et la vitesse de la courroie. La capacité de la courroie est donc une quantité connue; sinon elle peut être calculée à partir des formules de la CMA. Pour les réseaux simples de convoyeurs, la disponibilité mécanique et électrique est si élevée que l'on peut, aux fins de contrôle de la production, considérer les réseaux comme étant toujours utilisables.

Un système EG-convoyeur-trémie fonctionne essentiellement en mode séquentiel continu. On utilise habituellement davantage la simulation dans deux autres situations : passages multiples dans un processus séquentiel continu afin de déterminer la distribution des résultats possibles, et études des files d'attente dans des processus discrets. Dans les sections du modèle EG qui conviennent davantage aux techniques de simulation, on utilise des formules empiriques plutôt que des distributions statistiques. Toutefois, l'idée d'employer la méthode de simulation est intéressante, ne serait-ce que parce qu'elle oblige l'utilisateur éventuel du programme à envisager la fourchette des résultats possibles - par exemple, s'il y a panne d'excavateur, quelle sera la durée du temps mort?

512 DOCUMENTATION

La documentation devrait pouvoir aider l'utilisateur éventuel à comprendre la façon dont un programme réalise ses fonctions. La documentation devrait également permettre à l'utilisateur de lancer le programme à l'aide de ses propres données et l'aider en cas de difficultés.

Les trois modules qui composent le modèle global EG-convoyeur-trémie sont accompagnés d'une documentation qui décrit clairement la théorie sous-jacente au programme. En ce qui concerne la compréhension de la théorie, l'impression générale qui se dégage de la documentation est donc très favorable.

Toutefois, les modules sont beaucoup moins utiles lorsque vient le moment d'aider l'utilisateur à introduire ses données et à lancer le programme. Deux lacunes graves sont manifestes. La documentation indique de façon implicite que les modules trémie et convoyeur emploient des fichiers de données dont les formats sont "libres". Cependant, les données introduites en format libre ne donneront rien, et il faut introduire les données exactement de la façon indiquée dans les exemples fournis à cet effet : virgules pour séparer toutes les variables et indiquer la fin d'un enregistrement, pas d'espaces internes, et points décimaux pour les variables réelles. La documentation ne donne aucun avertissement et il n'y a pas de vérification interne des données visant à assurer que celles-ci soient à l'intérieur des limites acceptables des formules empiriques et des dimensions du programme.

Les documents ne comportent pas de section "En cas de difficultés". Les incidents d'exécution qui provoquent l'affichage de messages du système d'exploitation peuvent se produire aisément. En outre, la documentation ne décrit même pas les arrêts commandés par le programme.

Un utilisateur qui n'est pas un programmeur FORTRAN accompli aurait probablement de la difficulté à faire fonctionner le simulateur à l'aide de ses propres données.

513 FONCTIONNEMENT

Le simulateur est difficile à mettre en marche. Il faut préparer un grand nombre de fichier de données, et les formats de plusieurs fichiers sont moins flexibles que nous le souhaiterions. Le module EG est doté d'un écho d'entrée utile dont devraient également être dotés les autres modules. Par contre, les modules convoyeur et trémie possèdent une fonction utile de mise au point qui devrait également être utile pour le module EG.

La façon d'indiquer au simulateur la géologie et la séquence d'exploitation est peu commode et devrait être revue. Donnons un exemple extrême : la façon d'indiquer les couches revient à dicter la méthode opérationnelle, alors que ce devrait être le contraire.

L'affichage au terminal est bon. Les informations affichées sont utiles et permettent de contrôler la simulation de façon appropriée. Cet aspect du modèle ne nécessite pas de modifications.

Nous avons peu utilisé les menus d'interruption. En général, ils semblent appropriés, mais ils ne couvrent pas la fourchette très large des options opérationnelles possibles. Donnons un seul exemple : on ne peut pas passer d'un abattage en gradin à un abattage au marteau-pilon au milieu d'un passage, même si la résistance exercée par les matériaux change le long d'un gradin et rend cette modification nécessaire. Également, nous n'avons pu ajouter ou supprimer le wagon sur courroie au milieu d'un passage.

Le modèle donne deux sorties imprimées. Tous les mouvements de l'excavateur à godets sont enregistrés sur FOR021.DAT. Cette sortie imprimée est très utile. Les changements d'état du réseau de convoyeurs ou des trémies sont enregistrés dans le rapport principal PRINT.DAT lorsque l'interrupteur approprié de mise au point est activé. Les modifications d'état des convoyeurs et des trémies devraient pouvoir être sorties sur FOR021.DAT.

PRINT.DAT est la principale sortie imprimée. Les échos d'initialisation sont appropriés, bien que nous aimerions qu'il y ait également des échos des données d'entrée sur le convoyeur et la trémie. On peut obtenir ces échos (même si certains ont été convertis) en mettant en fonction l'interrupteur de mise au point approprié. En outre, une représentation graphique des distributions de Weibull permettrait à l'utilisateur de s'assurer qu'elles ont été employées correctement.

Il n'y a pas de rapport de production horaire de l'EG. Le rapport n'indique nulle part le volume de matériaux qui est passé dans la trémie. Sinon, les rapports des divers volumes (totaux, par jour, par quart et par heure) sont appropriés.

Le simulateur a été incapable de prendre en charge la procédure opérationnelle relativement simple représentée par l'étude de cas n^o 3 de Monenco. Il est sans aucun doute incapable de prendre en charge les études de cas formulées par Krupp, lesquelles sont beaucoup plus complexes. Pourtant, il ne s'agit pas là de méthodes opérationnelles inhabituelles. Pour être utile, le simulateur doit posséder une plus grande souplesse d'utilisation qu'à l'heure actuelle.

Le module EG est incapable de calculer correctement les volumes abattus et les heures de fonctionnement de la machine. Le problème semble être attribuable à un problème d'indice interne caché quelque part dans le code.

5.2 SUGGESTIONS POUR L'AMÉLIORATION DU MODÈLE

On devrait apporter les modifications suivantes afin que le simulateur soit mieux adapté à l'enlèvement des morts-terrains :

a) supprimer toute référence à la méthode d'abattage latéral;

b) supprimer le concept de couches et introduire une hauteur variable de gradin;

c) supprimer toutes les références à la teneur des matériaux;

d) ajouter, dans le modèle du convoyeur, une fonction pour la station intermédiaire de transport et l'épandeuse;

e) donner aux fichiers d'entrée un format vraiment libre;

f) supprimer toutes les références à plus d'une pièce d'équipement d'alimentation;

g) supprimer les formules empiriques de la CEMA et de Rasper; en faire des programmes autonomes qui seront utiles pour les études du choix des dimensions de l'équipement;

h) remplacer les formules de Rasper par des distributions statistiques que l'utilisateur du programme peut introduire;

i) rédiger une section "En cas de difficultés" et l'ajouter à la documentation;

j) accroître les possibilités de mise au point du module EG; ajouter l'écho d'entrée aux modules convoyeur et trémie;

k) accroître la fourchette des options que peut modifier l'utilisateur en cours de simulation;

l) décrire les convoyeurs comme étant des machines à déplacement indépendant, de sorte que le wagon sur courroie et l'empileur puissent être modélisés comme des convoyeurs; et

m) modifier le programme de façon qu'il puisse modéliser des convoyeurs à courroie transporteuse entraînée par câble et des convoyeurs sur pente prononcée.

Ces modifications reviennent en fait à réécrire au complet le module EG et à apporter des modifications importantes au module convoyeur. On peut difficilement évaluer le temps nécessaire à ces modifications. Comme approximation très grossière toutefois, on peut dire que deux années-personnes devraient permettre de réaliser un produit dont on aura fait l'essai et qui offrira une certaine souplesse et une certaine facilité d'utilisation.

5.3 CONCLUSIONS

L'industrie minière canadienne a besoin d'un produit semblable au modèle excavateur-convoyeur-trémie. En fait, le besoin le plus pressant est un produit qui permettra de mieux choisir l'équipement et les méthodes améliorées d'exploitation.

À l'heure actuelle, un modèle de convoyeur serait fort bienvenue. Plusieurs types de travaux et d'équipement auraient besoin des évaluations fournies par un tel modèle : chargement direct à la pelle dans les broyeurs mobiles; postes de broyage installés en permanence sur le terrain; évacuation des matériaux hors de la cuvette par transporteur installé sur une pente prononcée; machinerie d'exploitation souterraine continue.

Suncor est actuellement la seule société minière canadienne qui emploie un excavateur à godets pour l'enlèvement des morts-terrains. TransAlta envisage d'installer un système EG-convoyeur pour l'enlèvement des morts-terrains à sa mine Highvale.

Le simulateur CNRC-CANMET n'est pas encore en mesure de répondre aux besoins de l'industrie.

La conception du simulateur EG-convoyeur-trémie a pris fin de manière abrupte avec l'annulation du projet Canstar d'exploitation des sables bitumineux, en 1982. Le simulateur porte les traces de cette fin soudaine. Certaines parties des codes n'ont jamais été écrites, et le simulateur ne donne pas toujours des résultats exacts.

Il sera nécessaire de revoir en profondeur le simulateur, en particulier le module EG, afin d'en faire un produit qui pourra être utile pour l'industrie.

Il y aurait lieu, également, d'étudier les produits de même nature offerts sur le marché avant d'investir davantage dans le simulateur CNRC-CANMET.

5.4 RECOMMANDATIONS

Dans sa forme actuelle, le simulateur EG-convoyeur-trémie n'est pas prêt à être employé par l'industrie canadienne. Il faudrait le modifier en profondeur, en particulier le modèle EG, afin qu'il soit, même partiellement, un outil efficace pour le contrôle de la production à court terme, ce qui est la raison première de sa conception.

Avant de faire cet investissement, nous recommandons que CANMET étudie les produits qui sont actuellement offerts sur tous les marchés mondiaux et qui pourraient répondre aux besoins à court ou à long terme de l'industrie canadienne. Si l'on trouve de tels produits, nous recommandons qu'ils soient évalués en fonction d'un ensemble de critères établis au préalable et que le programme qui offre les meilleures possibilités soit évalué de la même manière que le simulateur CNRC-CANMET.

En outre, nous recommandons que des investissements additionnels soient consentis dans le simulateur CNRC-CANMET uniquement si une recherche approfondie sur les marchés mondiaux ne permet pas de trouver un produit de remplacement satisfaisant pour le contrôle de la production à court terme. Le cas échéant, il serait préférable de réécrire le module EG plutôt que de tenter de l'améliorer.

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PART 1

INTRODUCTION

1.0 INTRODUCTION

1.1 INTRODUCTION

The computer-based simulation model of bucket wheel excavators, conveyors and bins was developed several years ago as part of the CANSTAR oil sands project. The simulator was working, but not fully validated nor ever actually used, at the time the CANSTAR project was cancelled.

CANMET issued contract 23440-5-9249/01-SQ in order to assess the applicability of the simulation model to general industry needs. The Study Objective and Work Statement are included in this report under Section 1.2

Monenco's project team approached the project as the evaluation of a piece of software that was virtually ready for routine usage within industry. The impression that the software development was complete was reinforced by a software demonstration held at the CANMET offices March 5, 1986.

The Terms of Reference were modified at the Initial Meeting of June 9, 1986 because the CANSTAR consortium had disbanded, and at another meeting on August 8, 1986 after it had become apparent that the simulation model was still in the development stage and far from complete. The minutes of these two meetings are included in this report under Section 1.3.

1.2 TERMS OF REFERENCE

This report is structured to address the Study Objective and Work Statement prepared by the CANMET Coal Research Laboratory and included here:

OBJECTIVE

On behalf of the Department of Energy, Mines and Resources, CANMET, Coal Research Laboratories, the contractor is required to assess, evaluate and validate, using four supplied case histories, an existing computer based simulation model of bucket wheel excavators, conveyors and bins that has been developed for surface mining applications.

BACKGROUND

The model to be assessed, evaluated and validated was developed a number of years ago as part of a feasibility study for a new surface mine. Its main purpose was to compare the performance of the alternative mining schemes and equipment systems being considered. In addition it was expected that the model might serve a number of subsidiary purposes, e.g. training of operating crews, specifying production bottlenecks, setting production standards, etc. The model, developed by a team of engineers, was never fully validated nor used for its intended purpose. A working version of the software was available on a VAX-11/750 computer at the Coal Research Laboratory, Calgary.

Although the team responsible for developing the model had disbanded some individuals were still accessible. The purpose of this contract was to obtain an independent assessment of the model to determine whether it might now be used or modified for use by industry.

WORK STATEMENT

1. Examine the provided software documentation and comment on the validity, completeness and general adequacy of at least the following:

   - simplifying assumptions which reduce the mining system to a manageable analytical model,

   - model logic and mathematical relationships used to represent events and operations; values assigned to parameters, statistical data on variables, rationality of relationships;

   - interface linkages between the three constitutive modules,

   - command menus and their correspondence to controllable functions available in real life,

   - input data needed to initiate the model, and

   - output reports for common decisions made in mine design, operations, etc.

2. Operate the program using default data and make essential adjustments as required.

3. Examine case-study data, prepare validation exercises and conduct validation tests on the provided case studies. Comment on the sensitivity of the model to critical variables and opportunities for simplification and focussing of the model to specific cases.

1.3 MODIFICATIONS TO TERMS OF REFERENCE

131 MINUTES OF INITIAL MEETING

The initial meeting was held at the CANMET offices in Calgary on June 9, 1986. In attendance were:

Albert Chan, NRC
Josef Sedlacek, Monenco
Val Srajer, CANMET, Scientific Authority
Jozef Szymanski, CANMET
Michael Wise, Monenco, Project Manager

Mr. Srajer advised that CANSTAR has closed their offices, so that no CANSTAR test cases will be used. Instead, there will be three test cases, all of which are at Pit 04 at Highvale Mine. The three cases are:

a) Prestripping overburden on east-west cuts using a single bucket wheel on two benches. Waste will be handled by a round-pit conveyor system.

b) Prestripping overburden on north-south cuts using a single BWE discharging to a round-pit conveyor system on the upper overburden multi-bench.

c) Prestripping overburden on north-south cuts using a single BWE on the lower overburden multi-bench and discharging to a long cross-pit conveyor.

Mr. Srajer emphasized that he was particularly interested in how the simulator could be improved, for example improving the flow logic or making changes to the equations. He did not want the consultant to actually solve the problems listed as "test cases" in the Addendum to the Request for Proposal, but rather he wanted the consultant to determine if the simulator would be useful to solve those problems. The experiments in Monenco's proposal were acceptable to him.

Dr. Chan expressed concern over the applicability of the simulator for longer term planning. At a minimum he felt programming would be required to delete the interactive prompts and remove the display. Messrs. Wise and Sedlacek felt that TransAlta would be most interested in the longer range questions such as equipment sizing.

It was ultimately agreed that the first priority of the study would be answering longer term questions, with short term (weekly/monthly) questions addressed only if time and money permit.

Mr. Srajer also requested that the report address questions such as what information would be most appropriate in the display and report for tarsands, overburden, and coal operations.

Mr. Wise asked Dr. Chan to confirm his availability in case of problems. Dr. Chan responded that he would prefer not to have to return to Calgary when most problems could be solved over the telephone, but would make himself available in Ottawa to provide assistance. For example, the BWE model requires two terminals, but remote operation would permit only one terminal to be logged onto the system. He will change program to meet our requirements.

Dr. Chan agreed to contact Greg Gibb, writer of the BWE model, to ask his cooperation.

Mr. Wise expressed his intention to not look at the source code. The others agreed that this was not part of the consultant's mandate.

Mr. Srajer advised that CANMET is moving to Edmonton, and that the CANMET computer would be unavailable the last week of June or the first week of July, with "not more than five working days disruption to computer services".

132 MINUTES OF MEETING AUGUST 8, 1986

The draft review meeting was held at the Monenco offices in Calgary on August 8, 1986. In attendance were:

J. Sedlacek, Monenco
V. Srajer, CANMET, Scientific Authority
M. Wise, Monenco, Project Manager

The following items were discussed at the meeting:

- Mr. Wise advised that due to deficiencies in the simulator, progress towards testing the simulator using real data was very slow. Most importantly, restrictions within the program have required that the test case be modified to meet the program restrictions, thus making any comparison of results to other sources impossible.

  Specific problems discussed were: formats of the input data files; restrictions on block model coordinates; restrictions on the BWE hinge height.

  Mr. Wise advised that he would attempt to complete the two-bench Monenco test, but without much expectation of success. The two Krupp cases are more complicated than the Monenco test cases.

In response to this presentation, Mr. Srajer agreed that in view of the number of difficulties encountered to date there was no need to perform all three test cases. Mr. Srajer instructed Mr. Wise to stop testing and devote all efforts to clearly presenting the difficulties encountered in the final report.

Mr. Srajer advised that he wanted to see an estimate in the final report of the length of time required to rewrite and error-check the program so that it would be completely useful for an overburden-stripping operation at any coal mine.

- The final report would be presented in draft form at a meeting in the Monenco offices on August 22, 1986 at 9:00 a.m.

1.4 POTENTIAL NEEDS OF INDUSTRY

Suncor Mining uses bucket wheel excavators for stripping the overburden above the tarsands at Fort McMurray. The overburden is loaded into trucks that drive underneath the discharge boom of the BWE. This is the only Canadian mine that uses the BWE.

Syncrude makes use of bucket wheel reclaimers to reclaim windrows of tarsands. The tarsand is transported to the extraction plant by conveyor.

Several base metal mines make use of in-pit crushing and conveying. Island Copper and Gibraltar are two Western Canadian mines that use this practice for transporting copper ore.

The underground coal mines of Cape Breton make extensive use of conveyors for shipping the coal from the face to the surface.

All the above mines are potential candidates for use of a simulator that is able to model the short-term operation.

The Highvale Mine of TransAlta Utilities is the leading candidate for future installation of a BWE-conveyor system for overburden removal. Planning is underway, with system installation planned for the mid-1990's.

Many Canadian open pit mines need software that would improve the decision-making for capital expenditures that improve productivity. The productivity improvements are relatively small. For example, a truck dispatch system may result in an overall 5% improvement in operating cost; the improvement due to trolley assist would be in the same order of magnitude. Software similar to the conveyor simulator could be useful to examine alternatives such as a mobile crusher directly behind the shovel; installation of a permanent in-pit crusher; comparison of standard versus high-angle conveyors leading out of the pit.

The Elkford operation of Fording Coal Limited is one mine that is actively considering a wide range of alternate coal and waste rock transportation systems.

Canadian underground mines also are evaluating methods of improving materials-handling productivity. A product similar to the conveyor simulator could be useful to examine alternatives to LHD equipment such as continuous muckers that feed onto conveyors.

For TransAlta and other mines, the product that would be most useful would be one that helped with equipment sizing and selection. Such a product would put more emphasis on longer-range planning, for example over a year or longer.

A simulation program will be desirable where the operator is facing the installation of a complex conveying system, planning to implement BWE systems, or considering a capacity increase. Equipment manufacturers frequently make recommendations for different-sized equipment and different operating methods.

An independent program that could test these equipment selections and operating procedures would be very useful. The object would be primarily to check if the recommendation really does meet requirements, and secondly to determine which of several diverse recommendations from several suppliers is most cost-effective.

Although the mine operator may be interested in what any system can process in an hour, a shift or a month, there will be demand for the long term simulation of complex operations before the major expenditure is committed.

A good flexible simulation program will be welcomed by the industry.

1.5 POTENTIAL USES OF SIMULATOR

The BWE, Conveyor and Bin/Hopper models could potentially be used by the Mine Operation Department for crisis management, or by the Engineering Department for short-term, medium-term, and long-term planning and for equipment selection studies.

The simulator was originally envisioned as a tool for the Mine Operations Group. Two applications that were contemplated were as a training tool for supervisory staff, and as an on-line tool for equipment redeployment studies during an actual equipment malfunction.

We consider that it is potentially useful as a training tool for the pit foremen. They can get experience at dealing with equipment breakdowns and other problems so that when they are on their own in the field they can make better decisions.

We feel that the simulator, while it may potentially be useful for on-line monitoring, will require very significant upgrading to be useful for that task. In particular, there must be improved statistics of breakdown frequency and times to repair certain types of breakdown, there must be a method of keeping the files of equipment position and the block model up-to-date, and there must be greater flexibility in operating method and interactive prompts.

We consider that the simulator would be most useful in the Engineering Department. It could be particularly helpful for providing weekly, monthly and annual production budgets, so long as the information in the block model is sufficiently accurate. As with on-line monitoring, improved statistics of breakdown frequency and the time to make specific repairs are a requirement for effective use here.

Finally, the simulator would be useful for equipment selection studies or studies to examine alternate equipment redeployment. Examples of studies where either the BWE simulator or the conveyor model could be useful are: evaluation of in-pit crushing and conveying; capability of an existing conveyor network to handle higher production; evaluation of a different preventive maintenance schedule; BWE sizing studies; BWE vs. truck/shovel studies. These longer term studies particularly require good interaction between the model and the geometry of the mining layout as well as improved statistics of operational and repair times.

PART 2

EXAMINATION OF SOFTWARE DOCUMENTATION

2.0 EXAMINATION OF SOFTWARE DOCUMENTATION

2.1 INTRODUCTION

In accordance to Work Statement 1 in the Terms of Reference, we critically examined the documentation with regard to general applicability to industry and checked the underlying assumptions with Rasper's "The Bucket Wheel Excavator" and the Conveyor Equipment Manufacturers Association empirical formulae.

The simulation model of a bucket wheel excavator, conveyor and bin/hopper operation is supported by the following documentation:

LTR-CS-227	An Interactive Simulation Model of Conveyor Systems in Tar Sands Mining - Systems Model Report
LTR-CS-229	An Interactive Simulation Model of Conveyor Systems in Tar Sands Mining - Computer Model Report
LTR-CS-231	An Interactive Simulation Model of Bin/Hopper Systems in Oil Sands Mining
-	Users Guide - Interactive Model of an Open-Pit Mine Bucket Wheel Excavator Model
-	Programmer's Guide - Interactive Model of an Open-Pit Mine Bucket Wheel Excavator Model

We found that system logic and mathematical formulae are well-explained in the documentation, and generally in order. Specific exceptions to this follow below.

We did find that the terminology used is not always clearly explained and furthermore it does not always coincide with the accepted usage in the mining industry. This problem occurred most often with the BWE model. Specific examples are the terms "block", "bench", "layer", "section", "cut". These were sources of considerable confusion.

The documentation does not have an "In Case of Difficulty" section for any module. As was found during the testing phase of the project, run failures that result in operating system messages can easily occur, and even the program halts that are program-controlled are not described in the documentation.

We found that the BWE module as presently constituted is heavily oriented towards tarsands operation, and particularly the type of operation envisioned for CANSTAR. Examples of this orientation are the concern with material grade, boulder frequency, and layers. This orientation adds a level of complexity to the module that could be removed if the model were used for modelling a waste stripping operation.

The conveyor model and the bin/hopper model have more general applicability. One obvious weakness of the conveyor model was the assumption that the dump point is always the conveyor head station. No allowance was made for a movable tripper car along the length of the belt.

2.2 BIN/HOPPER MODULE

Monitoring of the fullness of the bin should also take into account the loads on the conveyors from the feeding source to the bin. This way the bin will never be overloaded and downtime of the feeding equipment will be minimized. From a computer programming point of view it may be preferable to keep the bin/hopper model an independent module but we cannot envision practical engineering problems that do not have it connected to some feeding device and outflow device.

Another weakness of the bin-full event is that all feeding equipment has to stop. It would be preferable if when dealing with multiple sources of feed single items could be shut down sequentially, thus keeping some production going. If the bin were replaced by a stacker, only the full or empty states should apply. The "bin empty" warning would also be redundant.

In the overburden-only case, particularly if the bin were replaced by a stacker, the events shown in Table 4.0.1 of LTR-CS-231 could be considerably simplified. Table 4.0.1 is reproduced in this report as Table 1 of Appendix D.

2.3 CONVEYOR MODULE

The conveyor model has been constructed using the empirical formulae published by the Conveyor Equipment Manufacturers Association. While some may disagree with these, they are in common use in North America and we have no quarrel with their use.

In many situations, the cable belt conveyor or various forms of high angle conveyor are viable alternatives to the tensioned belt conveyor. For completeness, these types of conveyor should also be included in the conveyor module.

The documentation of the conveyor model is particularly complete. We appreciated the explanation of the model in LTR-CS-227 and the existence of the computer code in LTR-CS-229. However, we found that some of the code has been changed since LTR-CS-229 was published. This is discussed in Section 4.2. The meanings of certain factors in Section 3.1.5 of LTR-CS-227 could have been more fully explained. They are not obvious without consulting the appropriate reference.

We do not like the mixture of Imperial and SI units used on input.

We disagree with the philosophy used in Section 3.1.2 of LTR-CS-227. According to Section 3.1.2, belt speed is calculated from the maximum conveyor capacity and an arbitrary capacity factor, both of which are input parameters. In all studies that we can imagine the conveyor simulator would be used for, belt speed would be an input, and capacity would be a calculated quantity.

Belt weight should be input according to the type of belt. The formula used in Section 3.1.3 however, could be useful for general equipment-selection type of studies.

Feeding locations and dumping location should be infinitely variable. The extra tension resulting from a tripper station needs to be included. In Table 3.9.2 (Table 2 in Appendix D), the elevation of the feeding points are not included. The belt could be installed over an undulating surface, so feeding point elevation is required.

In Table 3.9.5 (Table 3 in Appendix D), we feel that overhaul should be included in the down time.

There needs to be a connection between events 307 and 301. See Table 4.1.1. (Table 4 in Appendix D).

In the case of a conveyor breakdown (Section 3.4 of LTR-CS-227), it may not always be possible to make the one-half turn to empty the belt. Under winter freezing conditions it is not desirable to stop a conveyor unless absolutely necessary. Section 3.5 (of LTR-CS-227) needs special logic to turn off the feeding equipment but keep the preceding belts running.

The practical purpose of event 320 seems very limited. It is applicable only to a conveyor with two head stations or for special repair purposes.

2.4 BUCKET WHEEL EXCAVATOR MODULE

The main reference on which the BWE model is based is Rasper's "The Bucket Wheel Excavator". We have examined this reference (and others) as well as the BWE model documentation, and find no fault with the underlying theory and empirical equations that are used in the BWE model, with the following exceptions.

In Figure 4.2E the assumption

$$t \leq w < h\ 2/3\ D \text{ should read}$$
$$t \leq w; \quad h \leq 2/3\ D$$

where:
t = thickness of slice
w = bucket width
h = depth of cut
D = wheel diameter (including buckets)

In Paragraph 4.1.4.20, the formula for CS:

$$CS = 2.22 \times FAC \times 2\ R \text{ should read}$$
$$CS = 2.22 \times FAC \times (2R)^{1/2}$$

where:
CS = cutting speed
FAC = factor to calculate cutting speed
R = bucket wheel radius

In Paragraph 4.1.4.61, the statement that slewing speed for the drop cut is double the slewing speed of the bench cut (i.e. SSDROP = 2SS) is neither explained nor substantiated. We could not find the equivalent relationship in Rasper.

In Paragraph 4.1.4.77, if BDEP $>$ R then

$$ANG = \pi/2 + SIN^{-1}\ [(BDEP-R)/R] \times \pi/180$$

where:
ANG = cutting angle
BDEP = depth of cut
R = wheel radius
TLC = total length of cutters

In Paragraph 4.1.4.100, the requirement TLC = 2 x TLC for winter only is not clearly explained. We would assume that the BWE has a number of precutters equal to the number of buckets the whole year round.

In Paragraph 4.1.4.120, the factor K which is expressed in kg/cm should be referred to as a cutting resistance rather than a digging resistance. Digging resistance customarily has units kg/cm^2. In the input files, BLOCK5 and BLOCK6 are supposedly the summer and winter digging resistance (kg/cm^2), but in the input echo the units are kg/cm which implies cutting resistance.

In Paragraph 4.1.4.162, the symbols in the equation

$$SF = \frac{DBR \times WSS \times CF}{BL}$$

are not identified. A little later in the text, BLTWT is also not identified, but we believe that it refers to the weight of the belt in question.

The program also needs a test to ensure that the drop cut method can be applied only when the bench height to the top of the top layer is less than the selective mining height of the BWE.

We feel that the program is unnecessarily complicated by the inclusion of the lateral cut and the drop cut.

The lateral cut on which the majority of the program was based was developed for a type of BWE that moved on rails laid parallel to the mining face. Alernatively, it was used with a crawler-mounted BWE that had a rigid (non-slewable) discharge boom. Both methods are now obsolete.

The pure drop cut is seldom used because the operator would have to pay a severe penalty for oversizing the BWE.

Current design parameters almost always allow for the first layer to be excavated by the bench cut. The other layers then can be excavated by either the bench or drop cut. The height of the working face is matched to the maximum height reach of the BWE when the top layer is removed by the bench cut method. Only if the working face is lower than the maximum height (specifically 0.65D lower, where D is the wheel diameter) could the pure drop cut be a practical alternative.

The assumption that the model will stop during the slice only for a boulder delay may not be adequate. Bucket damage or a sudden power outage may prevent the machine from completing the slice. However, this may not have any practical effect on the computations.

In Paragraph 4.1.4.1 it is apparent that all slices and layers are assumed identical. In practice, the digging thickness will vary to allow the most effective cutting scheme as well as to satisfy the free angle restriction.

The drop cut method used in the program is apparently based on the Suncor Mining methodology. This method may be specific to Suncor and may not be optimal or applicable for general use.

There is some confusion about the value for the boom length as it is not clear throughout the report if the "real boom length" is used instead of a more restrictive definition. Common usage in the industry measures the boom length as the distance between the hinge point and the center of the wheel. The "real boom length" consists of boom length plus wheel radius plus bucket height. Common usage in the industry also includes the bucket height as part of the wheel radius.

Confusion also exists over the "bucket length". We believe the text uses this term to mean "bucket height", while common usage of the term bucket length refers to the length of the contact point between the wheel and the bucket, along the circumference of the wheel. Bucket length does not influence "real boom length" or "wheel diameter".

The formula used in Paragraph 4.1.4.320 to calculate the distance restriction due to boom angle is not shown but we know that it is hard-coded into the program. As is discussed in Section 422 the formula is so restrictive that it dictates rather than accepts the geometry of the BWE.

The distance restriction formulated in Paragraph 4.1.4.350 for the track restriction is in our opinion too restrictive. We see nothing wrong with letting the tracks touch the toe of the face. This is desirable in order to secure as much advance as possible.

In Paragraph 4.5.6.50 the end of the section for the lateral cut should be based on the end of the bottom layer.

The Table of Contents lists a section called 4.7 Miscellaneous Routines. This section is missing from the Programmer's Guide.

Our research into the code has indicated that certain parts of the BWE action have not yet been coded. Particularly noteworthy is the code relating to on "end of section". Dr. Chan inserted some makeshift code to permit the testing of the actual field cases, but this is not nearly as elaborate as the fully-operational model would need to be.

Problems with layer definition, mining block definition and the passing of coordinates from block model to BWE module to conveyor module are discussed in Section 3.2.

PART 3

OPERATION OF MODELS USING DEFAULT DATA

3.0 OPERATION OF MODELS USING DEFAULT DATA

3.1 CONVEYOR - BIN/HOPPER MODEL

The conveyor-bin model was the first test case examined. The test case represents the situation shown in Figure 3-1.

Once "file protection errors" that were a product of the CANMET VAX 11/750 operating environment were overcome, the program ran without errors using the default data. The documentation was only moderately adequate to guide making subsequent changes to the base data files. Specific gaps in the documentation were: silence in regard to the files GASP.DAT and INPOUT.DAT, and the discussion of CONVEY.DAT did not include mention of the additional lines that had been added for non-interactive initialization.

Because of the inadequacy of the documentation with regard to GASP.DAT, it was necessary to refer to the source code (published in LTR-CS-229 Computer Model Report) to find how to change the speedup factor and set the random number seed to make all runs identical. We never did find where the material swell factor and density were hidden.

We appreciated the detail of the documentation with regard to the equations and theory underlying the conveyor and bin/hopper models, and the listing of the source codes.

We would have liked an echo of the input parameters to appear in the output report. With this exception, the report was generally adequate to allow determination of what was going on.

The BWE simulator creates a file of all the events that transpired during the course of the simulation. The events that occur within the conveyor and bin/hopper models should also be written to FOR021.DAT.

We were unable to determine what the column "PR.RAT BCM/HR" signified, since often the value here exceeded the production capacity of the feeding equipment. Conveyor cycle time does not merit the prominence it receives, particularly since the conveyor initialization report yields this information. Improved discussion of the output reports in the documentation might have cleared up the confusion. The report for the bin/hopper could have included the volumes that had passed into and out of the bin. These numbers appear on the screen display, but not in the report.

The mixture of Imperial and SI units on input was an unnecessary source of confusion. Even worse was the mixture of BCM and LCM in the output report. The output report does not show swell factors, so checking of material balances was virtually impossible.

While the feeding equipment report was meagre, it was still infinitely better than the total lack of an hourly production report in the BWE model. We could not find the raw data that runs the conveyor model.

A series of runs were made on the conveyor-bin model. The models were run to simulate a single 8-hour shift. The random number seed was set at an odd integer (7) in order to make each run identical. The screen update factor was set at 3600 in order to update the screen display once an hour. The list of experiments run is shown in Appendix A. A single parameter was changed in each run, and the results compared to the expected result. The interactive property of the simulator was not used.

The detail in the output report, and the level of detail in the documentation, was adequate to determine that the program behaves the way the documentation says it is supposed to, and that the results are reasonable. The basic formulae were validated from the results of Experiments 1 and 2.

The conveyor model has been set up with capacity as an input quantity, belt width as an optional input quantity, and belt speed as a calculated quantity. The input parameter "maximum conveyor speed" is apparently never used in these calculations (Note Experiments 3-8 and 10-14). According to Section 3.1.1 of LTR-CS-227 it is used only if belt width is not specified. Since the model will most likely be used at operations where belt width and speed are fixed for a particular installation, we prefer that belt width be an input, belt speed an optional input, and capacity be a calculated quantity. The overload condition would occur when the feeding equipment supplies too much material onto the belt.

In Experiment 15, one of the conveyors was placed on a 15% upgrade. This simulated an in-pit conveying system. The output showed the conveyor was 87% efficient at raising material up the slope. This value is considered reasonable.

Mountain-top mining was simulated in Experiment 16, in which a conveyor was put on a 15% downgrade. The simulation indicated that the conveyor was able to recover 92% of the potential energy of the drop in elevation. This value is also considered reasonable. The output report is unable to handle a downhill grade of more than 9.99% without a format error. This experiment also was able to provide a measure of the amount of regenerative energy that the downhill haul is capable of generating. This is a useful piece of information. However, the program should also have the capability of "applying the brakes" when the conveyor energy consumption falls below zero.

The attempt was made in Experiment 18 to run the simulator for a full year. The screen update factor was changed to 86400; with only one screen update daily, it took approximately 50 seconds to process all the events of a single day. Much of this time was spent updating the screen at 1200 baud.

The run was terminated after 8 simulated days because screen output of almost continuous "output conversion error" slowed processing to a crawl. This format error occurred because the feed equipment production report was formatted for a maximum operating time of 9999 minutes. Dr. Chan of NRC was asked to check all output formats to ensure that the screen display and output reports are compatible to a long-term run.

The ability to change the seasonal productivity factor during a run would be of assistance in a longer run. So would introduction of 2 other distributions: downtime due to weather, and time between delays caused by weather.

3.2 BUCKET WHEEL EXCAVATOR - CONVEYOR - BIN MODEL

The set-up of the test case for the BWE-Conveyor-Bin model is shown in Figure 3.2.

The initial problems with running this model were caused by difficulties that related to the CANMET VAX 11/750 operating system. Once these were cleared up, the program operated using the default data, although several false starts were necessary because the BWE simulator requires a lot of interactive input. The documentation was of no assistance at leading the user through this interactive session.

The datafiles that the simulator uses require preknowledge of the method of operation of the simulator, so the interactive session that sets up the method of operation seems redundant. It was also unclear why questions relating to initialization reports and frequency of production reports had to be asked twice. The final 2 questions, that give the user the opportunity to adjust some BWE attributes and the mining sequence, seem particularly inappropriate, because of the effort that went into the datafile preparation in the first place.

The documentation was written at a time when the BWE model was standalone. It has since been combined with the conveyor and bin models. In this test example, while the documentation describes files MISC.DAT, ISENSW.DAT, and SENSW.DAT, those files do not exist in the test example. SEED.DAT is supposed to contain a single value for generating all the other random numbers; it actually contained 11 lines of what appeared to be various switches. Dr. Chan subsequently determined that the missing files have been replaced by GASP.DAT and SEED.DAT is not used at all; the random number seed is located in GTSEED.DAT.

The purpose of file PITCHG.DAT is not clearly explained.

Other products of this not-quite-perfect merging of the two models are 2 speedup factors: TUPM in ATRIB.DAT, and ISPEED in GASP.DAT, and 2 random number seeds: SEED in GASP.DAT, and the single value in GTSEED.DAT.

Although the data file indicates that the simulation was supposed to start at 9 A.M., it began at 8 A.M. regardless of the value placed in HROFST in ATRIB.DAT. Although IATTEN was set to zero for no interactive interrupts, the model stopped for operator response at the start and end of every BWE breakdown. The histogram boundaries do not agree with the parameters input in HISTO.DAT.

The parameters JPAUSE, SLOTIM, and IDISFL in ATRIB.DAT are not described in the documentation.

Several changes were made to the original test case data.

In order to prevent the "bin full" condition, bin capacity and outflow were changed to 60,000 and 5,000 BCM/hr. Both speedup factors were made 3600 so that screen update occurred only every hour. The random number seed in GASP.DAT was changed to 7, but the other seed was left at 43947. The empty belt warning in CONVEY.DAT was briefly changed to 90 minutes, but this resulted in too many and confusing interactive interrupts. (A very thorough knowledge of the conveyor network is necessary before starting and stopping belts). The conveyor movement time was reset to 48 hours to eliminate a format error in the report.

The geographic coordinates of the block that was originally being mined is shown in Figure 3.3. These were changed to the configuration shown in Figure 3.4. This provides a picture closer to our view of reality.

This revised test case became the base for further exploration of the BWE modelling capabilities. The list of experiments run on this model is shown in Appendix A.

We appreciate the echo of the input parameters in the output report and the time history file FOR021.DAT. Both features should also be included in the conveyor-bin models.

A major source of difficulty with the BWE-Conveyor-Bin model occurs with the relationship between the geology (block) model and the coordinates of the BWE and conveyors. This topic is discussed at greater length in Parts 321 and 322.

With no hourly reports of BWE production, and no reports of the position of the machine within the blocks, it was impossible to determine if the simulator was making calculations in the manner stated in the documentation. Critical input parameters that are apparently hard-coded into the model are the power rating of the wheel and slew motors, and the rotational speed of the wheel. There is a discrepancy between the productivity of the #1300 BWE and the #1301 BWE, unless the 16-bucket machine has a rotational speed lower than the 10-bucket machine.

The productivity that the model predicts for the #1300 machine while in the bench-digging mode agrees quite closely to rule-of-thumb estimates.

We are uncomfortable with the way the "operator inefficiency factor" is applied. The factor as used here could be expressed as power used divided by power available. We prefer that operator inefficiencies show up as increased delays between slices, or increased tramming times.

The model indicates that drop cutting is only 70% as efficient as bench cutting. We feel that this should be closer to 90%. The reasons for this difference relate to the empirical equations used in the model. This problem has been mentioned in Section 2.4.

Since many mines occur in areas where the power supply is a problem, a useful output of the combined model would be a table or graph of energy requirements as a function of time, or perhaps a histogram of frequency of occurrence of various levels of energy draw.

We found that the BWE model will not accept a run longer than 20 shifts. We also found that there is a problem with material balance. In Experiment #29, the volume produced by the BWE did not match the volume delivered to the bin.

321 THE BLOCK MODEL

In our view, the method of handling the interface of the BWE to the mining material is totally inadequate. The concept of using blocks that match the mining cuts is acceptable; for example this is the method used by the MINEX mine planning system. But while MINEX uses a flexible database approach to the problem of storing geological and mining information, the BWE simulator uses two cumbersome ASCII files: DDBASE.DAT and SEQ.DAT.

Other mine planning systems calculate reserve quantities directly from a regular 3-dimensional or gridded seam model. Transformations of the data into the special mining model can be difficult.

Our understanding is that the block width in DDBASE.DAT corresponds to the width of the mining bench that the BWE will mine in one pass down the length of the pit. It must be constant. The block length is arbitrary, and depends upon the degree of variability of the material grade (for tarsands) or hardness, but all blocks must have the same length. Because the BWE module was set up for tarsands, it was assumed that there would be different classes of strata within the full cutting height of the BWE, so the total bench was divided into layers. All layers in DDBASE.DAT must be the same height, and the entire mining area must have the same number of layers. The set-up therefore is basically a 3-dimensional block model.

In the test case, the layer height is equal to the wheel radius of the BWE. It would be fortunate indeed if in a true tarsands operation the ore and centre reject thicknesses were at some constant multiple of the wheel diameter! The essence of grade control is to keep the ore and waste as separate as possible, and this is not approached in the current arrangement. We would prefer that, as a minimum, the thickness of each layer be individually specified, and the length of each block (which may contain several layers) be individually specified.

The shapes of pits are not necessarily rectangular with straight cuts, but these restrictions are built within the block-handling logic. Freedom of the section/column/layer specification from a regular block model specification would improve flexibility, although mine coordinates of the block boundaries may have to be carried within the block parameters.

We also found it confusing that in a multi-bench operation, there must be a separate block model for each bench of the operation.

In Experiments 24-27 and 29-32, we experimented with attempts to force the BWE model to reach the end of a section and start on a new section. This required adjustments to both DDBASE.DAT and SEQ.DAT; the changes made are noted in Appendix A. We had a great deal of difficulty getting the revised models to work; the cryptic message "there are xx cases where there are a different number of layers than this sequence calls for" kept appearing on the screen during the interactive input session. While we were (apparently) able to have a single BWE change to a different section, we never did manage to get the model working when operating both BWEs.

Furthermore, we found the terminal messages that are supposed to control the BWE and conveyor movements very confusing, and the documentation of no assistance whatsoever. According to Greg Gibb, author of the BWE model, there was supposed to be a message relating to the box cut on the new section; we did not encounter this. And finally, we were never able to get the BWE back into production after the section move; it remained on IDLE for the remainder of the simulation. Nor did the output reports show evidence of any conveyor moves.

During this "end-of-section" interrupt, the terminal shows an x,y distance that the conveyor is supposed to move. We have no idea what these numbers signify, since they bear no relationship to what we expect our geometric positioning to be.

Only after this testing was done did we learn that the FORTRAN code for the "end of section" and subsequent events had never been written!

322 COORDINATES SPECIFICATION

The coordinates of the mining block, the coordinates of the conveyors, and the coordinates at which the BWE dump onto the face conveyor are input into files DDBASE.DAT and CONVEY.DAT at the start of the simulation and are echoed in the output report. We also know that the x,y position of the BWE is supposed to be one of the attributes passed on from the BWE model to the conveyor model.

Neither the screen display nor the output report provided any information about the BWE movements once the simulation began. We have no idea whether this part of the BWE-Conveyor-Bin model works or not, or even if the system really CARES about the relative positions of anything. When we examine the block model coordinates in the original test data (Figure 3.3), it certainly looks as if this facet of the problem is ignored.

In the original test data, both BWEs use a belt wagon that allows a total belt length of 75 metres. However, the initial condition report shows the separation between the first block model coordinate and the loading point on the face conveyor to be only 10 metres. Once again, we were unable to determine if any checks are made regarding relative positions of the blocks, BWE, and conveyor.

The screen display keeps track of the section, column, and layer that the BWE is mining. In the course of our experiments we examined bench cuts, drop cuts, and the combination method. We are unable to say with any conviction that this part of the model works. For example, in Experiment #32 the counter quickly moved to (1,2,4) and stuck there for most of the 20 shifts involved in this simulation, although the volume delivered to the extraction plant kept going up. In this experiment, the delivered volume far exceeded the volume along a single section, yet the "end of section" interrupt was never reached.

In Monenco Test Case 3 (Section 423), the layer index apparently stuck at 3, and the column index cycled randomly among the blocks along the row.

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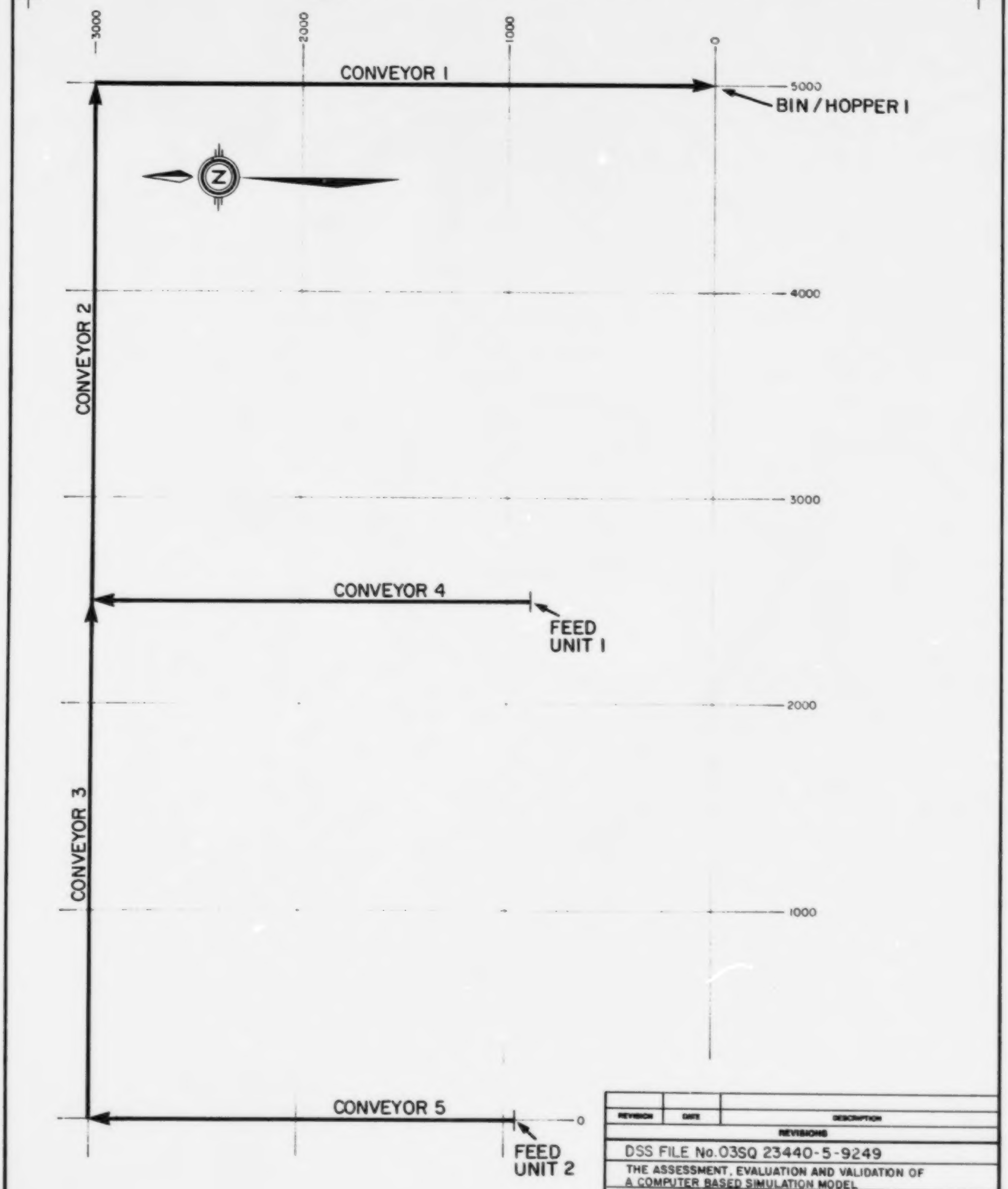


3000
2000
1000
0
CONVEYOR 1
5000
BIN / HOPPER I
4000
CONVEYOR 2
3000
CONVEYOR 4
FEED UNIT I
2000
CONVEYOR 3
1000
CONVEYOR 5
0
FEED UNIT 2

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

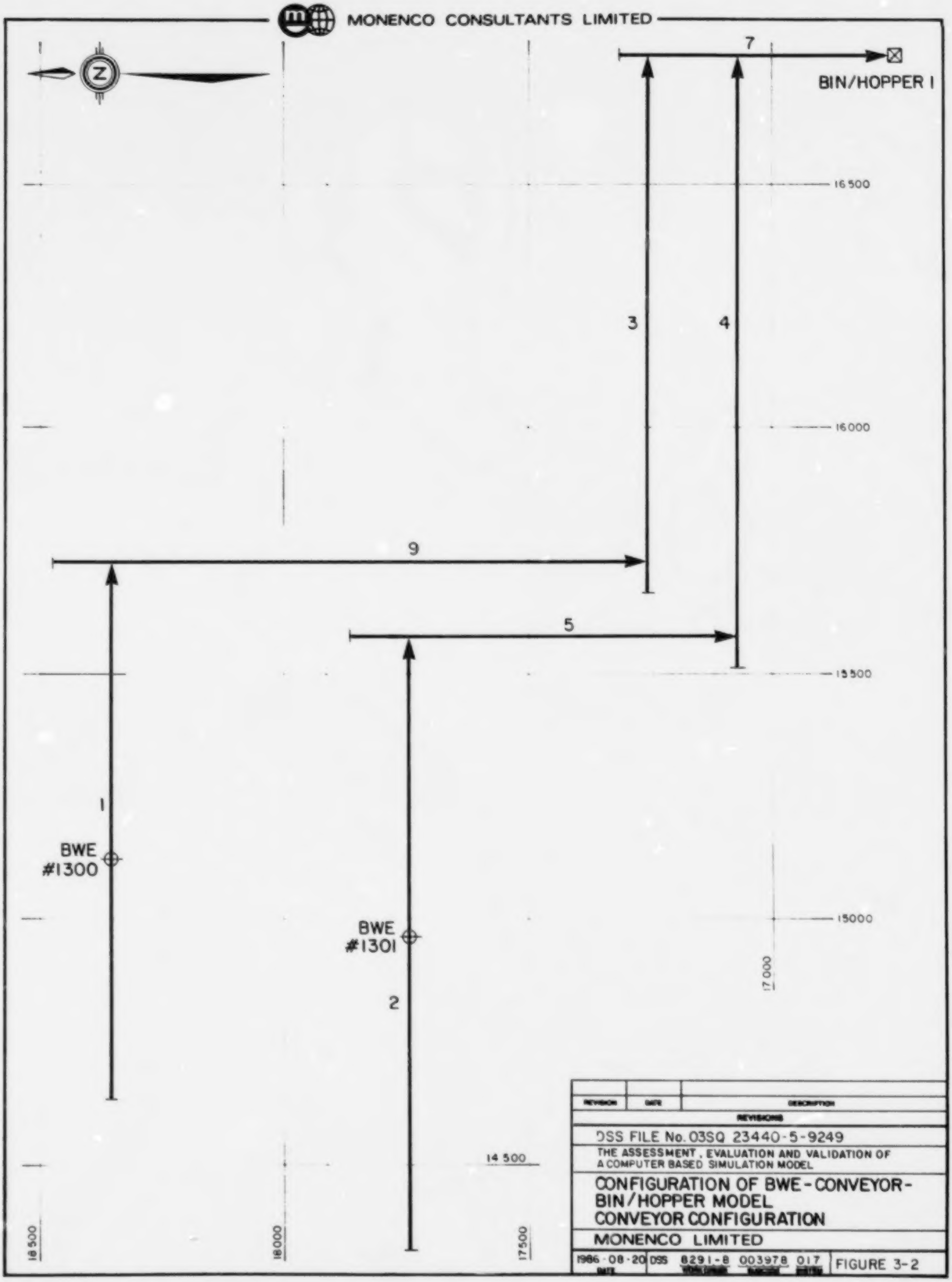
THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

CONFIGURATION OF
CONVEYOR-BIN/HOPPER MODEL

MONENCO LIMITED

1986-08-20 DATE | DSS 8291-8 003978 017 | FIGURE 3-1

MONENCO CONSULTANTS LIMITED


Z
7
BIN/HOPPER I
16 500
3
4
16 000
9
5
15 500
1
BWE #1300
BWE #1301
15000
17 000
2
14 500
18 500
18000
17500

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

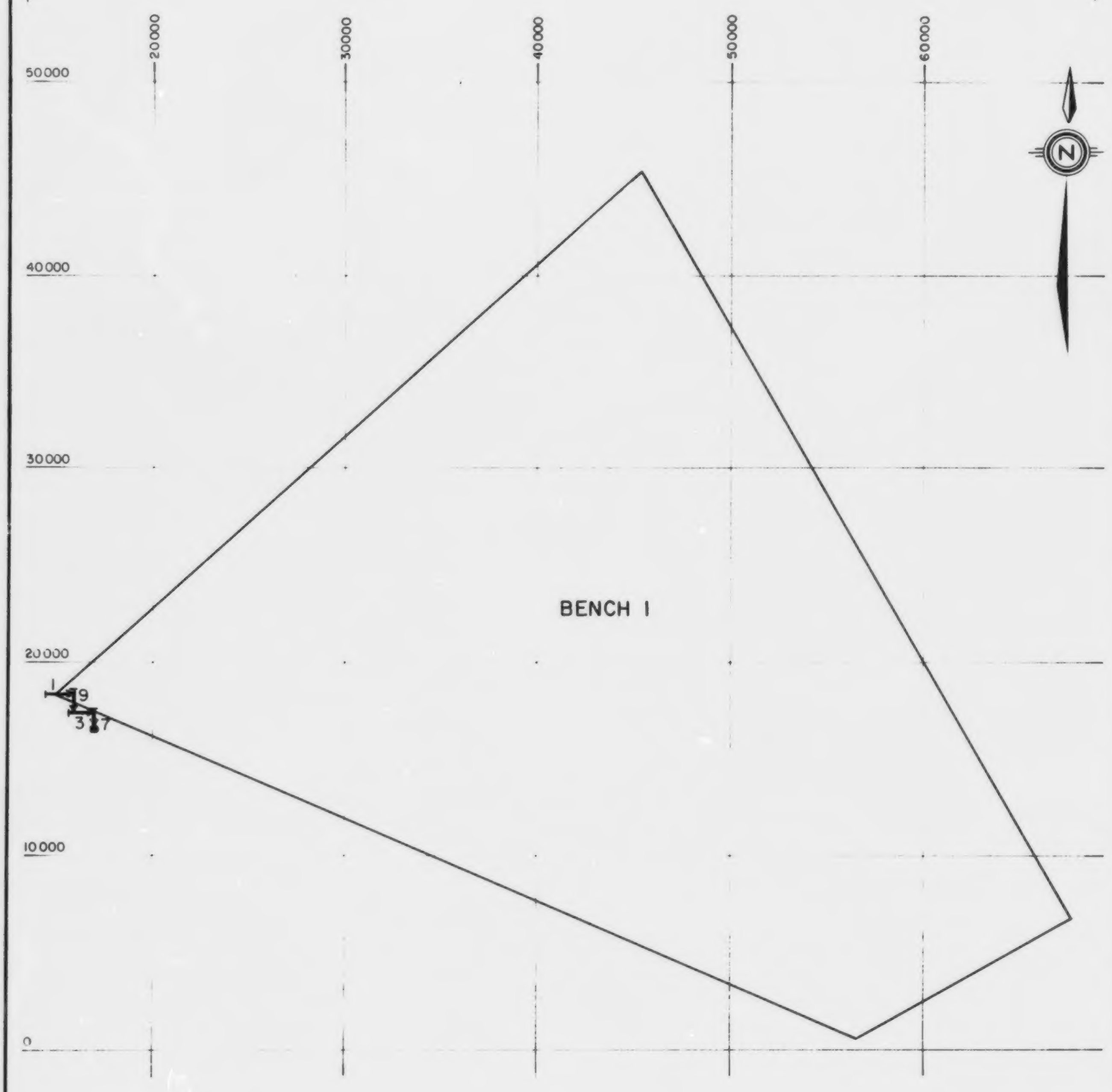
THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

CONFIGURATION OF BWE - CONVEYOR -
BIN / HOPPER MODEL
CONVEYOR CONFIGURATION

MONENCO LIMITED

1986 - 08 - 20 DSS 8291 - 8 003978 017

FIGURE 3-2


20000
30000
40000
50000
60000
50000
40000
30000
20000
10000
0
N
BENCH I
1
9
3
7

REVISION	DATE	DESCRIPTION

REVISIONS

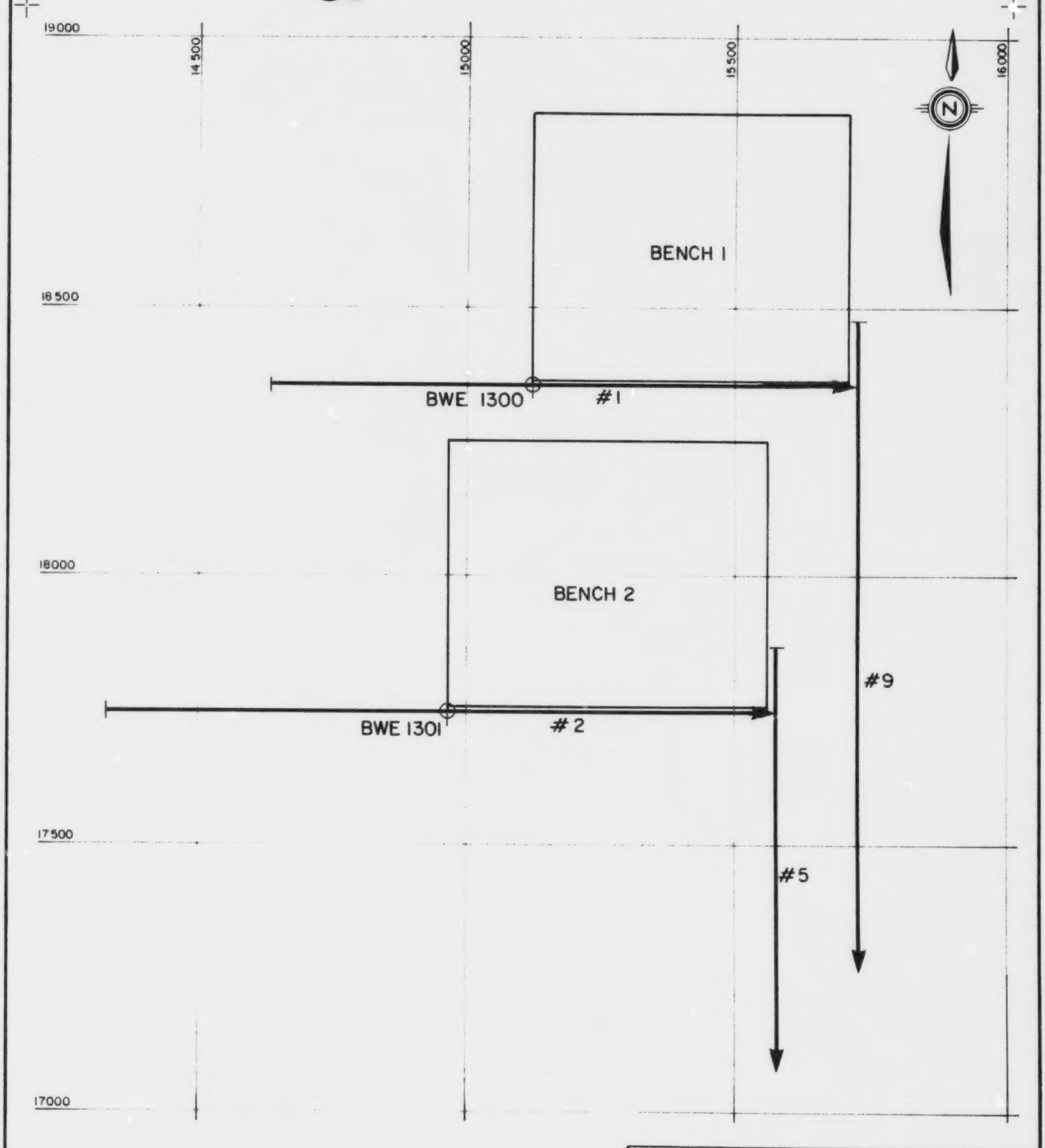
DSS FILE No. 03SQ 23440-5-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

CONFIGURATION OF BWE-CONVEYOR-
BIN/HOPPER ORIGINAL BLOCK MODEL
(BENCH I ONLY)

MONENCO LIMITED

1986-08-20 DATE	DSS 8291-8 003978 017 WORK ORDER SUBCODE SYSTEM	FIGURE 3-3


19000
18500
18000
17500
17000
14500
15000
15500
16000
N
BENCH 1
BENCH 2
BWE 1300
#1
BWE 1301
#2
#9
#5

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

CONFIGURATION OF BWE-CONVEYOR-BIN/HOPPER MODEL, REVISED BLOCK MODEL AND CONVEYOR CONFIGURATION

MONENCO LIMITED

1986-08-20 DATE | DSS 8291-8 003978 017 | FIGURE 3-4

PART 4

OPERATION OF MODELS USING TEST EXAMPLES

4.0 OPERATION OF MODELS USING TEST EXAMPLES

4.1 INTRODUCTION

All case studies are derived from Pit 04 at the Highvale Mine.

Highvale Mine is a large plains thermal coal deposit owned by TransAlta Utilities Corporation and mined under contract to Manalta Coal Ltd. Production from Pit 04 is currently 4 million tonnes per year, rising gradually to 4.8 million tonnes.

Pit 04 currently (1986) is in low overburden cover so all overburden can be removed from the coal using an M8050 dragline. The overburden will increase gradually in depth over time, so that in 1991 the M8050 machine is scheduled to be replaced by a larger M8750 dragline. After 1995 even the large dragline has insufficient capacity to remove the required overburden without prestripping assistance.

Previous studies commissioned by TransAlta had shown that one of the most cost-effective method of overburden removal (once prestripping is required) is the employment of a bucket wheel system. TransAlta commissioned two consultants to study operating methods and equipment sizing for the bucket wheel prestripping operation. Monenco Consultants Limited and Krupp Canada Incorporated made proposals that were different in both operating sequence and equipment selection.

It was hoped that the BWE-conveyor-bin model could be used to model the Monenco and Krupp proposals, and confirm the cost and productivity estimates offered by the two consultants. We modelled the geological conditions and the equipment operating environment, and ran various experiments to test how well the simulator could simulate the proposed systems.

4.2 MONENCO CASE STUDY

421 BUILDING THE MODEL

The Monenco case study relates to an east-west mining sequence in Pit 04 at Highvale Mine. The bucket wheel excavator will be used to prestrip overburden in advance of an M8750 dragline. The dragline will remove the lowermost 22 metres of overburden, leaving the remainder to be handled by the bucket wheel excavator. The arrangement of the cuts is shown on Figure 4-1, with the depth of overburden superimposed on the cuts.

The BWE to be used in the Monenco case study is a large Model 1900 bucket wheel excavator. The machine has a 13 m wheel diameter, has an expected output of 2700 bcm per operating hour, and can cut in single benches up to 30 m high or excavate the total height in front of a conveyor up to 40 m employing a 10 m high step (Figure 4-2).

Monenco Test Case 1 represents approximately one year of mining when the prestrip operation has just begun. The overburden removed by the BWE is less than 30 m thick (Figure 4-1).

Once the prestrippable overburden exceeds 30 m (and it is impractical to doze the excess into hollows along the length of the cut), it will be necessary to start a second bench. In Pit 04, this lower bench is a maximum of 10 m in height. Monenco Test Case 3 (Figure 4-1) represents approximately one year of mining in the late stages of Pit 04. The lower bench is almost continuously developed over its full 10 m height.

Monenco Test Case 2 (Figure 4-1) is intermediate between the overburden conditions of Test Cases 1 and 3.

The BWE will discharge directly onto a face conveyor when the machine is digging the first pass in either a single-bench mode or when digging the lower bench in the two-bench operation. A belt wagon will be employed between the BWE and the face conveyor for the second pass when the BWE is digging the upper bench of a two-bench system. The use of the belt wagon will halve the number of conveyor moves that would otherwise be required.

The cuts in Pit 04 were divided into blocks 200 m in length, and an average overburden depth was assigned to each block, to the nearest 5 m. The lowermost 22 m were assigned to the dragline, and the remainder was assigned to the BWE. Dozing was used to smooth out the peaks and valleys along the cuts.

Tables 4-1, 4-2 and 4-3 show the thickness of overburden and prestripping, the smoothed thicknesses of the upper and lower benches, and the thickness of the dozed cut and fill in each block for Monenco Test Cases 1, 2 and 3.

A FORTRAN program (DDBASE.FOR) was written in order to generate the data files DDBASE.DAT, SEQ.DAT and PITCHG.DAT that describe the geology model and mining sequence for the bucket wheel simulator. Even with the assistance of this program there is a lot of data entry required to build up these files. All blocks were assigned the same specific gravity and cutting resistance. Test Case 1 has only one bench that reaches a maximum of 25 m in thickness.

It was a straightforward, although time-consuming, task to prepare the datafiles that describe the bucket wheel excavator, conveyors and spreader. Since we knew already that the conveyor model would not accept a tripper/spreader, we substituted a shortened conveyor and a large-capacity bin. Also, since we had no reliability or repair time statistics for any of the equipment, we adopted the statistics that were used in the default case.

The equipment used in all three cases is very similar. The main difference is with the conveyor coordinates.

A separate block model is required for each test case, and for each bench of each test case. However, the models for the multiple-bench cases can be combined into a single DDBASE.DAT file.

The (X1, Y1) coordinate of each model was chosen on the northeast corner of each mining area. In all cases mining proceeded from east to west on the first cut, so (X2, Y2) was the northwest corner of the area to be mined. The block models were slightly rotated with respect to the mine coordinate system.

The experiments run using Monenco Test Case 1 are detailed in Appendix B, and the experiments run using Monenco Test Case 3 are shown in Appendix C.

422 MONENCO TEST CASE 1

The test case represents the initial position shown in Figure 4-3. The formats of the input files proved to be much more restrictive than indicated in the documentation. The format required is neither "fixed format" nor "free format", but some special combination. In addition, the formats listed in the source code (published in LTR-CS-229 and LTR-CS-231) do not work for files CONVEY.DAT, BIN.DAT AND CNSTAT.DAT. Some appreciation of the magnitude of this problem can be gleaned by reading the results of Experiment 34 in Appendix B.

The debug switches in INPOUT.DAT were useful for subsequent tracing of program problems. Unfortunately, the existence of file INPOUT.DAT is not mentioned in any report, so these debug switches were not activated during the experiments with the default data. The purpose of some of the debug switches is described in LTR-CS-227 for the conveyor model and LTR-CS-231 for the bin model. We were unable to find an equivalent debug capability for the bucket wheel model.

The programs do not have a sufficient number of internal checks for data compatability. The BWE model has a useful echo of input parameters in PRINT.DAT; a similar feature would be useful for the conveyor and bin models. Since the program uses a complex procedure to calculate the Weibull distribution parameters, it would be useful to have a confirming statement that each distribution is satisfactory. In Experiment 34(e), we received the cryptic message "undefined exponentiation" that we ultimately found to be caused by a keypunch error. The program was unable to help us narrow down the problem to a particular distribution. A superior check would be a line printer plot of the frequency and cumulative frequency of each distribution.

The most glaring example of poor internal data checking was revealed in Experiments 35(a) and 35(b). The bucket wheel model has been dimensioned for a maximum of 120 steps, 2 sections, 5 layers, and 10 columns. As will be shown in Section 423, we never successfully got Test Case 3 running and we suspect the difficulty is use of 5 layers.

On occasion, the input data according to the documentation has a different unit in the echo in PRINT.DAT. Examples are:

Item	Unit in Documentation	Unit in Printout Echo
REVSLT	Minutes	Seconds
ITIMPM	Minutes	Hours
INTPM	Minutes	Hours
RESMAX	kg/cm^2	kg/cm
BLOCK5	kg/cm^2	kg/cm
BLOCK6	kg/cm^2	kg/cm
BRTDST	Minutes	Hours
BOTDST	Minutes	Hours
ERTDST	Minutes	Hours
EOTDST	Minutes	Hours

The debug echo of conveyor parameters in some instances returns a value that has been modified by the program. This may be useful to the programmer, but is a minor source of delay and frustration to an "outsider" trying to get the program to run.

While the debug capability of the bin/hopper and conveyor modules are not quite perfect, at least the capability is there. We would have found a similar capability useful on the BWE module.

Experiment 36 revealed the restriction within the program:

$$\text{Hinge distance} \geq (\#\text{Layers} - 1) \times \text{Layer Thickness}$$

We have no idea where this comes from, as it is not supported in the literature nor by actual field conditions. This problem was not encountered in the default case because the layer thickness equalled wheel radius, hinge distance equalled three wheel radii, and the default case was a four-layer case. So in the default data:

$$3R = (4 - 1) \times R$$

However Monenco Test Case 1 has:

$$18.0 < (5 - 1) \times 5$$

so the program failed. In order to make the program work, we reset the layer thickness to 6.0 m and number of layers to 4 but did not regenerate the raw data of Table 4-1. As a result, the block model bears little resemblance to reality.

We were unsure what the correct input units into DDBASE.DAT were for "summer digging resistance". We used 7.0 kg/cm^2 as a digging resistance. The default data uses summer digging resistance of 33, which if measured in units kg/cm^2 would be solid granite. On the other hand, if the units are supposed to be kg/cm, a cutting resistance of 33 kg/cm would be very low. We tried to use a cutting resistance of 120 kg/cm as an input value in Experiment 37(f). The program did not like such a value.

We had difficulty getting material from the BWE onto the conveyors. The error messages that we received ("invalid feeder device 101 SIMTIM", and "error in new feeder location") were not particularly helpful. We ultimately found that the first message indicated that the BWE needed to know conveyor device numbers for both waste and ore, even though we were mining only waste and putting it onto the waste conveyor. The second error message indicated that our loading point was not between the eastings of the head and tail stations. Our interpretation of the source code of EVT301.FOR indicates that the equivalent test is not made on the northings of the head and tail station. Very small positioning errors on a north-south conveyor could cause the program to fail.

We ultimately determined that the BWE model has to be set up with increasing real coordinates along the x-axis. The model origin (X1, Y1) must be in the southwest corner of the model. Pit 04 is mined from north to south, and from east to west, so the logical origin was the northeast corner. As is shown in Experiments 37 and 38, this was not permitted.

All blocks have the same digging resistance, and all blocks were dug using the bench cut method. For some reason that we cannot explain the productivity of the BWE swung between 1646 bcm/hr and 3292 bcm/hr (as shown on the terminal output). Typically, the change in production occurred when the machine commenced production after a repair and remained at the same productivity level until the next breakdown.

Both Experiments 40 and 46 indicate that the BWE has a problem with accounting for layer volumes. The simulated BWE productivity is close to the theoretical productivity, so the problem must lie in the base volumetric measurements. The volume produced in Experiment 40 is only 20% of the volume of the blocks mined. The volume produced in Experiment 46 is only 15% of the volume of the blocked mined. Since the simulated BWE productivity is close to the theoretical productivity of the Model 1900 BWE, we conclude that the problem lies in either the base volumetric calculations, or there is an index problem similar to what is so evident in Monenco Test Case 3.

423 MONENCO TEST CASE 3

The test case represents the initial position shown in Figure 4-4. Both benches are fully developed over almost the total length of each cut.

Prior to running Test Case 3, Dr. Chan of NRC prepared a new version of the program with the capability of handling 1000 steps, 10 sections, 10 layers and 20 columns. A serious constraint on maximum size of the dimensions is that the array BLOCK is a 5-dimension array. With each possible bench, layer, section and column requiring 26 block attributes, the program will require enormous computational capacity unless the model size is restricted.

Unfortunately, the newer version of the program did not work, and since we were unable to contact Dr. Chan, we were forced to use the older version of the program that had limited dimensions. In addition, because of the hinge distance restriction, we had to increase the hinge distance of the Model 1900 BWE.

These changes to both the block model and the BWE attributes meant that the test case really did not match actual field conditions.

We quickly found that the simulator is unable to handle the case where the BWE is required to work on two benches. This is clearly shown in Experiment 42. We could have worked our way around this by defining a "dummy" BWE for the lower bench, then alternately activating and idling the two machines, but could not see the benefits of tricking the program in that manner.

Also in Experiment 42 we found that there is some maximum number of shifts that the simulator can handle. We were able to achieve results with 80 shifts specified, but the program failed to record any production when we specified 150 shifts.

Not only were we unable to get Monenco Test Case 3 to move to the second bench, we were unable to get the simulator to even finish the first section! Experiment 45 shows that the simulator cycles randomly between columns, with the layer indicator stuck at 3. We performed a detailed comparison of all data files used in Experiment 45 with those used in Experiment 46. The simulator was successfully able to switch between the sections of Monenco Test Case 1 in Experiment 46. Although several files have differences, we considered that the problem was either that the BWE was not geometrically capable of digging below layer 3 with the 24 m hinge distance, or that somewhere in the program there is an indexing problem.

Experiment 47 showed that the hinge distance was not the problem. Therefore, there appears to be an index problem hidden inside the program.

4.3 KRUPP CASE STUDIES

The two Krupp Case Studies relate to a north-south mining sequence in Pit 04 at Highvale Mine. Two bucket wheel excavators will be employed. They will be used to prestrip overburden in advance of an M8050 dragline. The dragline will remove the lowermost 15 metres of overburden, leaving the remainder to be handled by the bucket wheel excavators. The arrangement of the cuts is shown on Figure 4-5, with the depth of overburden superimposed on the cuts.

The BWEs that will be used in the Krupp Upper Bench and Krupp Lower Bench Case Studies are medium capacity Model C700S machines. The Model C700S BWE has a wheel diameter of 7.7 metres. The Upper Bench machine will be installed once overburden thicknesses exceed the capability of the single BWE.

The BWE that works on the lower system of benches will discharge the overburden onto a long cross-pit stacker that leads directly to the waste dump. This machine is installed first. The cutwidths employed are only 20 metres wide. This is half the width shown in Figure 4-5. The cross-pit conveyor will sit on the final dragline bench. The BWE will load directly onto the conveyor while digging the lower sub-bench, and will make use of a beltwagon while digging the upper sub-bench. This is illustrated in Figure 4-6.

The Upper system is more complex. In order to minimize conveyor moves, a maximum of four sub-benches can be developed. The face conveyor of a round-pit conveyor system is placed on the middle elevation. There are two benches above the level of the conveyor, with a belt wagon used when the BWE is on the uppermost bench to provide the required reach to the conveyor. There can also be two benches below the conveyor elevation, and once again a belt wagon is used to provide the necessary reach. The method of mining is shown in Figure 4-7.

Three test cases were developed for each case study. As with the Monenco Case Study, the test cases represent the beginning, middle, and end of the life of the prestrip operation in Pit 04.

431 BUILDING THE MODELS

Tables 4-4, 4-5 and 4-6 show the thickness of overburden and prestripping, the smoothed thicknesses of the benches of both the upper and lower system, and the thickness of the dozed cut and fill in each 40-metre wide block for Krupp Test Cases 1, 2 and 3.

The FORTRAN program DDBASE.FOR was used to generate the data files DDBASE.DAT, SEQ.DAT and PITCHG.DAT that describe the geology models and the mining sequence. This was done for the Upper and Lower system for the three test cases. Because the simulator requires all layers to be of an equal thickness, a layer thickness of 5 m was assigned, and each bench was an even multiple of the layer thickness. The original Krupp study had bench thicknesses (from top to bottom) of 15, 10, 16, 6, 9 and 7 metres. These were changed to 15, 10, 15, 5, 10 and 5 metre bench heights, as is shown in Tables 4-4, 4-5 and 4-6.

432 DISCUSSION

The Krupp test cases were not modelled using the simulator. The Monenco Test Case 3 had shown that the simulator was incapable of handling a two-bench operating system, while the Krupp Upper System uses 4 benches for the single machine. The movements of the BWE and belt wagon are also much more complex in the Krupp case than in the Monenco case, yet the simulator was not able to simulate even the Monenco situation.

Differences in bench heights caused by the required uniform layer thickness also meant that any comparison of results to previous studies would be meaningless.

A box cut method is used in the Krupp case for mining the lowermost bench of the upper system. There is no capability in the BWE simulator for handling this type of operating strategy.

Table 4-1

Evaluation of Bucketwheel Simulator

```
|-------------------------------------------------------------------------|
|           EVALUATION OF BUCKETWHEEL SIMULATOR                           |
|                     MONENCO TEST CASE #1                                |
|                                                                         |
|FILE: MEC01                                                              |
|DATE:       15-Jul-86                DL BENCH:          22 M             |
|----------|----------|----------|----------|----------|----------|
| BLOCK #  |  OVBDN   | PRESTRIP |  UPPER   |  LOWER   |  DOZED   |
|          |  DEPTH   |  DEPTH   |  BENCH   |  BENCH   |  HEIGHT  |
|----------|----------|----------|----------|----------|----------|
|       117|        22|         0|         0|         0|         0|
|       118|        27|         5|         5|         0|         0|
|       119|        37|        15|        15|         0|         0|
|       120|        47|        25|        25|         0|         0|
|       121|        37|        15|        15|         0|         0|
|       122|        37|        15|        15|         0|         0|
|       123|        37|        15|        15|         0|         0|
|       124|        32|        10|        10|         0|         0|
|       125|        32|        10|        10|         0|         0|
|       126|        37|        15|        15|         0|         0|
|       127|        37|        15|        15|         0|         0|
|       128|        37|        15|        15|         0|         0|
|       141|        37|        15|        15|         0|         0|
|       140|        37|        15|        15|         0|         0|
|       139|        37|        15|        15|         0|         0|
|       138|        37|        15|        15|         0|         0|
|       137|        37|        15|        15|         0|         0|
|       136|        37|        15|        15|         0|         0|
|       135|        37|        15|        15|         0|         0|
|       134|        37|        15|        15|         0|         0|
|       133|        47|        25|        25|         0|         0|
|       132|        42|        20|        20|         0|         0|
|       131|        27|         5|         5|         0|         0|
|       130|        22|         0|         0|         0|         0|
|       143|        22|         0|         0|         0|         0|
|       144|        27|         5|         5|         0|         0|
|       145|        47|        25|        25|         0|         0|
|       146|        47|        25|        25|         0|         0|
|       147|        37|        15|        15|         0|         0|
|       148|        37|        15|        15|         0|         0|
-------------------------------------------------------------------
```

Table 4-1 (cont'd)

Evaluation of Bucketwheel Simulator

```
|---------------------------------------------------------------------|
|              EVALUATION OF BUCKETWHEEL SIMULATOR                    |
|                       MONENCO TEST CASE #1                          |
|                                                                     |
|FILE: MEC01                                                          |
|DATE:       15-Jul-86                DL BENCH:         22 M          |
|----------|----------|----------|----------|----------|----------|
| BLOCK #  |  OVBDN   | PRESTRIP |  UPPER   |  LOWER   |  DOZED   |
|          |  DEPTH   |  DEPTH   |  BENCH   |  BENCH   |  HEIGHT  |
|----------|----------|----------|----------|----------|----------|
|      149 |       37 |       15 |       15 |        0 |        0 |
|      150 |       37 |       15 |       15 |        0 |        0 |
|      151 |       37 |       15 |       15 |        0 |        0 |
|      152 |       42 |       20 |       20 |        0 |        0 |
|      153 |       37 |       15 |       15 |        0 |        0 |
|      154 |       32 |       10 |       10 |        0 |        0 |
|      168 |       32 |       10 |       10 |        0 |        0 |
|      167 |       42 |       20 |       20 |        0 |        0 |
|      166 |       47 |       25 |       25 |        0 |        0 |
|      165 |       42 |       20 |       20 |        0 |        0 |
|      164 |       42 |       20 |       20 |        0 |        0 |
|      163 |       37 |       15 |       15 |        0 |        0 |
|      162 |       37 |       15 |       15 |        0 |        0 |
|      161 |       37 |       15 |       15 |        0 |        0 |
|      160 |       42 |       20 |       20 |        0 |        0 |
|      159 |       47 |       25 |       25 |        0 |        0 |
|      158 |       27 |        5 |        5 |        0 |        0 |
|      157 |       22 |        0 |        0 |        0 |        0 |
|      156 |       22 |        0 |        0 |        0 |        0 |
|---------------------------------------------------------------------|
```

Table 4-2

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
MONENCO TEST CASE #2

FILE: MEC02
DATE: 15-Jul-86 DL BENCH: 22 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	UPPER BENCH	LOWER BENCH	HEIGHT DOZED
309	27	5	5	0	0
310	37	15	15	0	0
311	37	15	15	0	0
312	42	20	20	0	0
313	52	30	30	5	5
314	62	40	30	5	-5
315	57	35	30	5	0
316	52	30	30	0	0
317	47	25	25	0	0
318	52	30	30	0	0
319	52	30	30	0	0
320	42	20	20	0	0
321	47	25	25	0	0
322	47	25	25	0	0
336	47	25	25	0	0
335	52	30	30	0	0
334	57	35	30	5	0
333	62	40	30	10	0
332	62	40	30	10	0
331	57	35	30	10	5
330	62	40	30	10	0
329	62	40	30	10	0
328	72	50	30	10	-10
327	67	45	30	10	-5
326	52	30	30	5	5
325	42	20	25	0	5
324	37	15	15	0	0
323	32	10	10	0	0
337	37	15	15	0	0
338	37	15	20	0	5

Table 4-2 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
MONENCO TEST CASE #2

FILE: MEC02
DATE: 15-Jul-86 DL BENCH: 22 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	UPPER BENCH	LOWER BENCH	HEIGHT DOZED
339	42	20	30	0	10
340	52	30	30	5	5
341	67	45	30	10	-5
342	77	55	30	10	-15
343	62	40	30	10	0
344	62	40	30	10	0
345	62	40	30	10	0
346	67	45	30	10	-5
347	62	40	30	10	0
348	57	35	30	10	5
349	52	30	30	0	0
350	47	25	25	0	0
364	52	30	30	0	0
363	57	35	30	5	0
362	57	35	30	10	5
361	62	40	30	10	0
360	67	45	30	10	-5
359	62	40	30	10	0
358	67	45	30	10	-5
357	62	40	30	10	0
356	72	50	30	10	-10
355	67	45	30	10	-5
354	52	30	30	10	10
353	47	25	30	0	5
352	42	20	25	0	5
351	37	15	15	0	0

Table 4-3

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
MONENCO TEST CASE #3

FILE: MECO3
DATE: 21-Aug-86 DL BENCH 22 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	UPPER BENCH	LOWER BENCH	HEIGHT DOZED
516	32	10	10	0	0
517	42	20	20	0	0
518	42	20	30	5	15
519	47	25	30	10	15
520	47	25	30	10	15
521	52	30	30	10	10
522	57	35	30	10	5
523	62	40	30	10	0
524	72	50	30	10	-10
525	87	65	30	10	-25
526	92	70	30	10	-30
527	72	50	30	10	-10
528	57	35	30	10	5
529	52	30	30	10	10
544	57	35	30	10	5
543	57	35	30	10	5
542	72	50	30	10	-10
541	92	70	30	10	-30
540	82	60	30	10	-20
539	67	45	30	10	-5
538	62	40	30	10	0
537	57	35	30	10	5
536	52	30	30	10	10
535	47	25	30	10	15
534	47	25	30	5	10
533	42	20	30	0	10
532	42	20	25	0	5
531	32	10	10	0	0
546	27	5	5	0	0
547	37	15	15	0	0

Table 4-3 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
MONENCO TEST CASE #3

FILE: MECO3
DATE: 21-Aug-86 DL BENCH 22 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	UPPER BENCH	LOWER BENCH	HEIGHT DOZED
548	47	25	30	0	5
549	47	25	30	5	10
550	47	25	30	10	15
551	52	30	30	10	10
552	57	35	30	10	5
553	62	40	30	10	0
554	67	45	30	10	-5
555	77	55	30	10	-15
556	82	60	30	10	-20
557	77	55	30	10	-15
558	57	35	30	10	5
559	57	35	30	10	5
574	57	35	30	10	5
573	62	40	30	10	0
572	82	60	30	10	-20
571	82	60	30	10	-20
570	77	55	30	10	-15
569	67	45	30	10	-5
568	67	45	30	10	-5
567	57	35	30	10	5
566	52	30	30	10	10
565	47	25	30	10	15
564	47	25	30	10	15
563	42	20	30	5	15
562	37	15	15	0	0
561	32	10	10	0	0

Table 4-4

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #1

FILE: KRUPP1
DATE: 22-Jul-86 DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM			DOZED HEIGHT	UPPER SYSTEM						
			TOTAL	UPPER	LOWER		TOTAL	TOP	2nd	DOZED	3rd	BOTTOM	DOZED
10	30	15	15	15	0	0	0	0	0	0	0	0	0
11	25	10	10	10	0	0	0	0	0	0	0	0	0
12	25	10	10	10	0	0	0	0	0	0	0	0	0
13	30	15	15	15	0	0	0	0	0	0	0	0	0
15	30	15	15	15	0	0	0	0	0	0	0	0	0
16	25	10	10	10	0	0	0	0	0	0	0	0	0
17	25	10	10	15	0	-5	0	0	0	0	0	0	0
18	35	20	20	15	0	5	0	0	0	0	0	0	0
20	35	20	20	15	0	5	0	0	0	0	0	0	0
21	30	15	15	15	0	0	0	0	0	0	0	0	0
22	25	10	10	15	0	-5	0	0	0	0	0	0	0
23	25	10	10	10	0	0	0	0	0	0	0	0	0
26	20	5	5	15	0	-10	0	0	0	0	0	0	0
27	35	20	20	15	0	5	0	0	0	0	0	0	0
28	35	20	20	15	0	5	0	0	0	0	0	0	0
29	30	15	15	15	0	0	0	0	0	0	0	0	0
30	30	15	15	15	5	-5	0	0	0	0	0	0	0
31	40	25	25	15	5	5	0	0	0	0	0	0	0
33	20	5	5	5	5	-5	0	0	0	0	0	0	0
34	40	25	25	15	5	5	0	0	0	0	0	0	0
35	40	25	25	15	5	5	0	0	0	0	0	0	0
36	30	15	15	15	5	-5	0	0	0	0	0	0	0
37	30	15	15	15	5	-5	0	0	0	0	0	0	0
38	40	25	25	15	5	5	0	0	0	0	0	0	0
40	20	5	5	15	0	-10	0	0	0	0	0	0	0
41	25	10	10	15	5	-10	0	0	0	0	0	0	0
42	40	25	25	15	5	5	0	0	0	0	0	0	0
43	40	25	25	15	5	5	0	0	0	0	0	0	0

Table 4-4 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #1

FILE: KRUPP1
DATE: 22-Jul-86 DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	UPPER	LOWER	DOZED HEIGHT	UPPER SYSTEM TOTAL	TOP	2nd	DOZED	3rd	BOTTOM	DOZED
44	40	25	25	15	5	5	0	0	0	0	0	0	0
45	35	20	20	15	5	0	0	0	0	0	0	0	0
46	40	25	25	15	5	5	0	0	0	0	0	0	0
47	20	5	5	5	0	0	0	0	0	0	0	0	0
48	25	10	10	15	0	-5	0	0	0	0	0	0	0
49	30	15	15	15	5	-5	0	0	0	0	0	0	0
50	40	25	25	15	10	0	0	0	0	0	0	0	0
51	45	30	25	15	10	0	5	5	0	0	0	0	0
52	45	30	25	15	10	0	5	5	0	0	0	0	0
53	40	25	25	15	10	0	0	0	0	0	0	0	0
54	40	25	25	15	10	0	0	0	0	0	0	0	0
55	20	5	5	5	0	0	0	0	0	0	0	0	0
56	25	10	10	15	5	-10	0	0	0	0	0	0	0
57	35	20	20	15	10	-5	0	0	0	0	0	0	0
58	40	25	25	15	10	0	0	5	0	-5	0	0	0
59	50	35	25	15	10	0	10	5	0	5	0	0	0
60	45	30	25	15	10	0	5	5	0	0	0	0	0
61	40	25	25	15	10	0	0	0	0	0	0	0	0
62	40	25	25	15	10	0	0	0	0	0	0	0	0
63	25	10	10	15	5	-10	0	0	0	0	0	0	0
64	30	15	15	15	5	-5	0	0	0	0	0	0	0
65	40	25	25	15	10	0	0	0	0	0	0	0	0
66	40	25	25	15	10	0	0	0	0	0	0	0	0
67	50	35	25	15	10	10	0	0	0	0	0	0	0
68	45	30	25	15	10	5	0	0	0	0	0	0	0
69	40	25	25	15	10	0	0	0	0	0	0	0	0
70	40	25	25	15	10	0	0	0	0	0	0	0	0
71	25	10	10	15	10	-15	0	0	0	0	0	0	0

Table 4-4 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #1

FILE: KRUPP1
DATE: 22-Jul-86 DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	LOWER SYSTEM UPPER	LOWER SYSTEM LOWER	DOZED HEIGHT	UPPER SYSTEM TOTAL	UPPER SYSTEM TOP	UPPER SYSTEM 2nd	UPPER SYSTEM DOZED	UPPER SYSTEM 3rd	UPPER SYSTEM BOTTOM	UPPER SYSTEM DOZED
72	35	20	20	15	10	-5	0	0	0	0	0	0	0
73	40	25	25	15	10	0	0	0	0	0	0	0	0
74	40	25	25	15	10	0	0	0	0	0	0	0	0
75	55	40	25	15	10	15	0	0	0	0	0	0	0
76	50	35	25	15	10	5	5	5	0	0	0	0	0
77	40	25	25	15	10	0	0	0	0	0	0	0	0
78	45	30	25	15	10	0	5	5	0	0	0	0	0
80	20	5	5	15	10	-20	0	0	0	0	0	0	0
81	40	25	25	15	10	0	0	0	0	0	0	0	0
82	45	30	25	15	10	5	0	0	0	0	0	0	0
83	40	25	25	15	10	0	0	0	0	0	0	0	0
84	55	40	25	15	10	10	5	5	0	0	0	0	0
85	50	35	25	15	10	5	5	5	0	0	0	0	0
86	40	25	25	15	10	-5	5	5	0	0	0	0	0
87	50	35	25	15	10	5	5	5	0	0	0	0	0
89	25	10	10	15	10	-15	0	0	0	0	0	0	0
90	40	25	25	15	10	-5	5	5	0	0	0	0	0
91	45	30	25	15	10	0	5	5	0	0	0	0	0
92	40	25	25	15	10	-5	5	5	0	0	0	0	0
93	55	40	25	15	10	10	5	5	0	0	0	0	0
94	55	40	25	15	10	10	5	5	0	0	0	0	0
95	40	25	25	15	10	-5	5	5	0	0	0	0	0
96	55	40	25	15	10	10	5	5	0	0	0	0	0

Table 4-5

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #2

LOWER SYSTEM 15 M
10 M

15 M
5 M
10 M
5 M

FILE: KRUPP2
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM			DOZED HEIGHT	UPPER SYSTEM					
			TOTAL	UPPER	LOWER		TOTAL	TOP	2nd	3rd	BOTTOM	DOZED
221	50	35	25	15	10	0	10	10	0	0	0	0
222	50	35	25	15	10	0	10	10	5	0	0	-5
223	60	45	25	15	10	0	20	15	5	0	0	0
224	70	55	25	15	10	0	30	15	5	0	0	10
225	60	45	25	15	10	0	20	15	5	0	0	0
226	55	40	25	15	10	0	15	15	5	0	0	-5
228	50	35	25	15	10	0	10	10	0	0	0	0
228	55	40	25	15	10	0	15	15	0	0	0	0
231	50	35	25	15	10	0	10	10	0	0	0	0
232	50	35	25	15	10	0	10	15	0	0	0	-5
233	65	50	25	15	10	0	25	15	5	0	0	5
234	75	60	25	15	10	0	35	15	5	0	0	15
235	60	45	25	15	10	0	20	15	5	0	0	0
236	50	35	25	15	10	0	10	15	5	0	0	-10
237	50	35	25	15	10	0	10	15	0	0	0	-5
238	55	40	25	15	10	0	15	15	0	0	0	0
241	45	30	25	15	10	0	5	10	0	0	0	-5
242	55	40	25	15	10	0	15	15	0	0	0	0
243	65	50	25	15	10	0	25	15	5	0	0	5
244	75	60	25	15	10	0	35	15	5	0	0	15
245	60	45	25	15	10	0	20	15	5	0	0	0
246	50	35	25	15	10	0	10	15	5	0	0	-10
247	50	35	25	15	10	0	10	15	0	0	0	-5
248	55	40	25	15	10	0	15	15	0	0	0	0
251	45	30	25	15	10	0	5	10	0	0	0	-5
252	55	40	25	15	10	0	15	15	0	0	0	0
253	65	50	25	15	10	0	25	15	5	0	0	5

Table 4-5 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #2

LOWER SYSTEM 15 M
10 M

15 M
5 M
10 M
5 M

FILE: KRUPP2
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	UPPER	LOWER	DOZED HEIGHT	UPPER SYSTEM TOTAL	TOP	2nd	3rd	BOTTOM	DOZED
254	75	60	25	15	10	0	35	15	5	0	0	15
255	60	45	25	15	10	0	20	15	5	0	0	0
256	50	35	25	15	10	0	10	15	5	0	0	-10
257	50	35	25	15	10	0	10	15	0	0	0	-5
258	60	45	25	15	10	0	20	15	5	0	0	0
262	45	30	25	15	10	0	5	5	0	0	0	0
263	50	35	25	15	10	0	10	15	0	0	0	-5
264	55	40	25	15	10	0	15	15	5	0	0	-5
265	75	60	25	15	10	0	35	15	5	0	0	15
266	60	45	25	15	10	0	20	15	5	0	0	0
267	50	35	25	15	10	0	10	15	0	0	0	-5
268	50	35	25	15	10	0	10	15	0	0	0	-5
269	65	50	25	15	10	0	25	15	5	0	0	5
273	40	25	25	15	10	0	0	10	0	0	0	-10
274	55	40	25	15	10	0	15	15	0	0	0	0
275	65	50	25	15	10	0	25	15	5	0	0	5
276	70	55	25	15	10	0	30	15	5	0	0	10
277	65	50	25	15	10	0	25	15	5	0	0	5
278	50	35	25	15	10	0	10	15	5	0	0	-10
279	50	35	25	15	10	0	10	15	5	0	0	-10
280	70	55	25	15	10	0	30	15	5	0	0	10
284	40	25	25	15	10	0	0	0	0	0	0	0
285	50	35	25	15	10	0	10	15	0	0	0	-5
286	65	50	25	15	10	0	25	15	5	0	0	5
287	65	50	25	15	10	0	25	15	5	0	0	5
288	65	50	25	15	10	0	25	15	5	0	0	5
289	50	35	25	15	10	0	10	15	5	0	0	-10
290	50	35	25	15	10	0	10	15	0	0	0	-5

Table 4-5 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #2

LOWER SYSTEM 15 M
10 M

15 M
5 M
10 M
5 M

FILE: KRUPP2
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	LOWER SYSTEM UPPER	LOWER SYSTEM LOWER	DOZED HEIGHT	TOTAL	UPPER SYSTEM TOP	UPPER SYSTEM 2nd	UPPER SYSTEM 3rd	BOTTOM	DOZED
291	65	50	25	15	10	0	25	15	5	0	0	5
295	40	25	25	15	10	0	0	0	0	0	0	0
296	50	35	25	15	10	0	10	15	0	0	0	-5
297	60	45	25	15	10	0	20	15	5	0	0	0
298	65	50	25	15	10	0	25	15	5	0	0	5
299	65	50	25	15	10	0	25	15	5	0	0	5
300	50	35	25	15	10	0	10	15	5	0	0	-10
301	55	40	25	15	10	0	15	15	0	0	0	0
302	65	50	25	15	10	0	25	15	5	0	0	5
306	40	25	25	15	10	0	0	0	0	0	0	0
307	50	35	25	15	10	0	10	10	0	0	0	0
308	60	45	25	15	10	0	20	15	5	0	0	0
309	60	45	25	15	10	0	20	15	5	0	0	0
310	65	50	25	15	10	0	25	15	5	0	0	5
311	55	40	25	15	10	0	15	15	5	0	0	-5
312	55	40	25	15	10	0	15	15	0	0	0	0
313	60	45	25	15	10	0	20	15	5	0	0	0
317	40	25	25	15	10	0	0	0	0	0	0	0
318	45	30	25	15	10	0	5	10	0	0	0	-5
319	60	45	25	15	10	0	20	15	5	0	0	0
320	60	45	25	15	10	0	20	15	5	0	0	0
321	65	50	25	15	10	0	25	15	5	0	0	5
322	55	40	25	15	10	0	15	15	5	0	0	-5
323	60	45	25	15	10	0	20	15	5	0	0	0
324	65	50	25	15	10	0	25	15	5	0	0	5

Table 4-6

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #3

LOWER SYSTEM 15 M
10 M

15 M
5 M
10 M
5 M

FILE: KRUPP3
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	LOWER SYSTEM UPPER	LOWER SYSTEM LOWER	DOZED HEIGHT	UPPER SYSTEM TOTAL	UPPER SYSTEM TOP	UPPER SYSTEM 2nd	UPPER SYSTEM 3rd	UPPER SYSTEM BOTTOM	UPPER SYSTEM DOZED
493	45	30	25	15	10	0	5	10	0	0	0	-5
494	60	45	25	15	10	0	20	15	5	0	0	0
495	60	45	25	15	10	0	20	15	5	5	0	-5
496	65	50	25	15	10	0	25	15	5	10	5	-10
497	65	50	25	15	10	0	25	15	5	10	5	-10
498	85	70	25	15	10	0	45	15	5	10	5	10
499	85	70	25	15	10	0	45	15	5	10	5	10
500	85	70	25	15	10	0	45	15	5	10	5	10
504	45	30	25	15	10	0	5	5	0	0	0	0
505	60	45	25	15	10	0	20	15	5	0	0	0
506	60	45	25	15	10	0	20	15	5	5	0	-5
507	65	50	25	15	10	0	25	15	5	10	5	-10
508	65	50	25	15	10	0	25	15	5	10	5	-10
509	80	65	25	15	10	0	40	15	5	10	5	5
510	85	70	25	15	10	0	45	15	5	10	5	10
511	85	70	25	15	10	0	45	15	5	10	5	10
515	45	30	25	15	10	0	5	5	0	0	0	0
516	55	40	25	15	10	0	15	15	0	0	0	0
517	55	40	25	15	10	0	15	15	5	0	0	-5
518	65	50	25	15	10	0	25	15	5	10	0	-5
519	65	50	25	15	10	0	25	15	5	10	5	-10
520	75	60	25	15	10	0	35	15	5	10	5	0
521	90	75	25	15	10	0	50	15	5	10	5	15
522	80	65	25	15	10	0	40	15	5	10	5	5
526	45	30	25	15	10	0	5	5	0	0	0	0
527	55	40	25	15	10	0	15	15	5	0	0	-5
528	55	40	25	15	10	0	15	15	5	0	0	-5

Table 4-6 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #3

LOWER SYSTEM 15 M 15 M
10 M 5 M
10 M
5 M

FILE: KRUPP3
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	L O W E R S Y S T E M TOTAL	UPPER	LOWER	DOZED HEIGHT	TOTAL	U P P E R S Y S T E M TOP	2nd	3rd	BOTTOM	DOZED
529	65	50	25	15	10	0	25	15	5	5	0	0
530	65	50	25	15	10	0	25	15	5	10	5	-10
531	75	60	25	15	10	0	35	15	5	10	5	0
532	90	75	25	15	10	0	50	15	5	10	5	15
533	80	65	25	15	10	0	40	15	5	10	5	5
537	45	30	25	15	10	0	5	5	0	0	0	0
538	50	35	25	15	10	0	10	10	0	0	0	0
539	55	40	25	15	10	0	15	15	5	0	0	-5
540	60	45	25	15	10	0	20	15	5	5	0	-5
541	65	50	25	15	10	0	25	15	5	10	0	-5
542	75	60	25	15	10	0	35	15	5	10	5	0
543	85	70	25	15	10	0	45	15	5	10	5	10
544	80	65	25	15	10	0	40	15	5	10	5	5
548	45	30	25	15	10	0	5	5	0	0	0	0
549	55	40	25	15	10	0	15	15	0	0	0	0
550	55	40	25	15	10	0	15	15	5	0	0	-5
551	60	45	25	15	10	0	20	15	5	5	0	-5
552	65	50	25	15	10	0	25	15	5	10	0	-5
553	75	60	25	15	10	0	35	15	5	10	0	5
554	80	65	25	15	10	0	40	15	5	10	5	5
555	80	65	25	15	10	0	40	15	5	10	5	5
559	45	30	25	15	10	0	5	10	0	0	0	-5
560	55	40	25	15	10	0	15	15	0	0	0	0
561	55	40	25	15	10	0	15	15	5	0	0	-5
562	60	45	25	15	10	0	20	15	5	5	0	-5
563	65	50	25	15	10	0	25	15	5	10	0	-5
564	75	60	25	15	10	0	35	15	5	10	0	5
565	80	65	25	15	10	0	40	15	5	10	0	10

Table 4-6 (cont'd)

Evaluation of Bucketwheel Simulator

EVALUATION OF BUCKETWHEEL SIMULATOR
KRUPP TEST CASE #3

LOWER SYSTEM 15 M
10 M

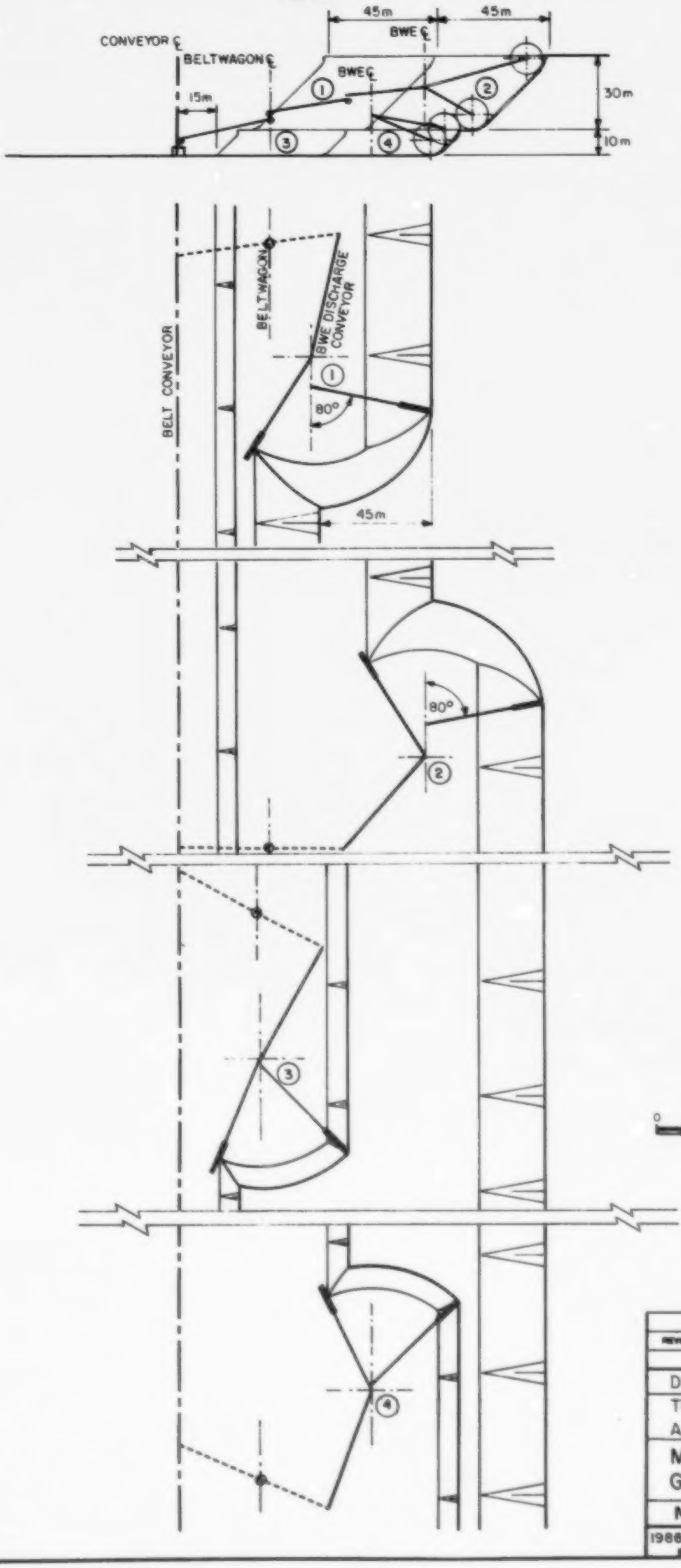
15 M
5 M
10 M
5 M

FILE: KRUPP3
DATE: 22-Jul-86

DL BENCH: 15 M

BLOCK #	OVBDN DEPTH	PRESTRIP DEPTH	LOWER SYSTEM TOTAL	UPPER	LOWER	DOZED HEIGHT	UPPER SYSTEM TOTAL	TOP	2nd	3rd	BOTTOM	DOZED
566	75	60	25	15	10	0	35	15	5	10	0	5
570	45	30	25	15	10	0	5	5	0	0	0	0
571	55	40	25	15	10	0	15	15	0	0	0	0
572	55	40	25	15	10	0	15	15	0	0	0	0
573	60	45	25	15	10	0	20	15	5	5	0	-5
574	65	50	25	15	10	0	25	15	5	10	0	-5
575	70	55	25	15	10	0	30	15	5	10	0	0
576	75	60	25	15	10	0	35	15	5	10	0	5
577	75	60	25	15	10	0	35	15	5	10	0	5
581	45	30	25	15	10	0	5	5	0	0	0	0
582	55	40	25	15	10	0	15	15	0	0	0	0
583	50	35	25	15	10	0	10	10	0	0	0	0
584	55	40	25	15	10	0	15	15	0	5	0	-5
585	65	50	25	15	10	0	25	15	5	5	0	0
586	65	50	25	15	10	0	25	15	5	10	0	-5
587	75	60	25	15	10	0	35	15	5	10	0	5
588	75	60	25	15	10	0	35	15	5	10	0	5
592	45	30	25	15	10	0	5	5	0	0	0	0
593	50	35	25	15	10	0	10	10	0	0	0	0
594	50	35	25	15	10	0	10	10	0	0	0	0
595	55	40	25	15	10	0	15	15	5	0	0	-5
596	65	50	25	15	10	0	25	15	5	5	0	0
597	65	50	25	15	10	0	25	15	5	10	0	-5
598	75	60	25	15	10	0	35	15	5	10	0	5
599	75	60	25	15	10	0	35	15	5	10	0	5

MONENCO CONSULTANTS LIMITED


45m
45m
BWE ℄
CONVEYOR ℄
BELTWAGON ℄
BWE ℄
①
②
15m
30m
③
④
10m
BELT CONVEYOR
BELTWAGON
BWE DISCHARGE CONVEYOR
①
80°
45m
80°
②
③
④
0
50
100
150METRES

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

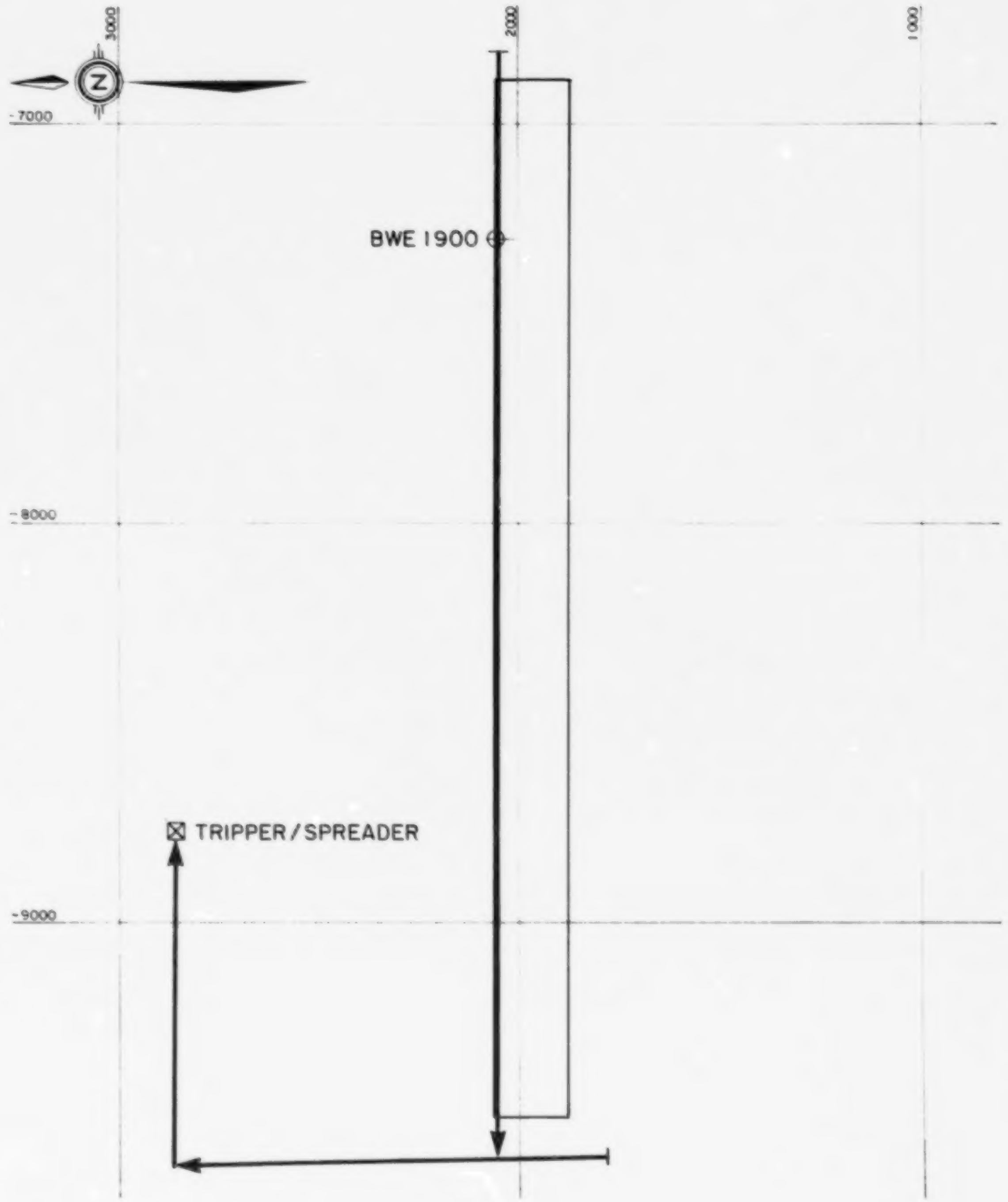
THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

MONENCO TEST CASES
GENERAL CUTTING DIAGRAM

MONENCO LIMITED

1986-08-20	DSS 8291-8 003978 017	FIGURE 4- 2

MONENCO CONSULTANTS LIMITED


3000
2000
1000
Z
-7000
-8000
-9000
BWE 1900
TRIPPER / SPREADER

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03 SQ 23440-5-9249

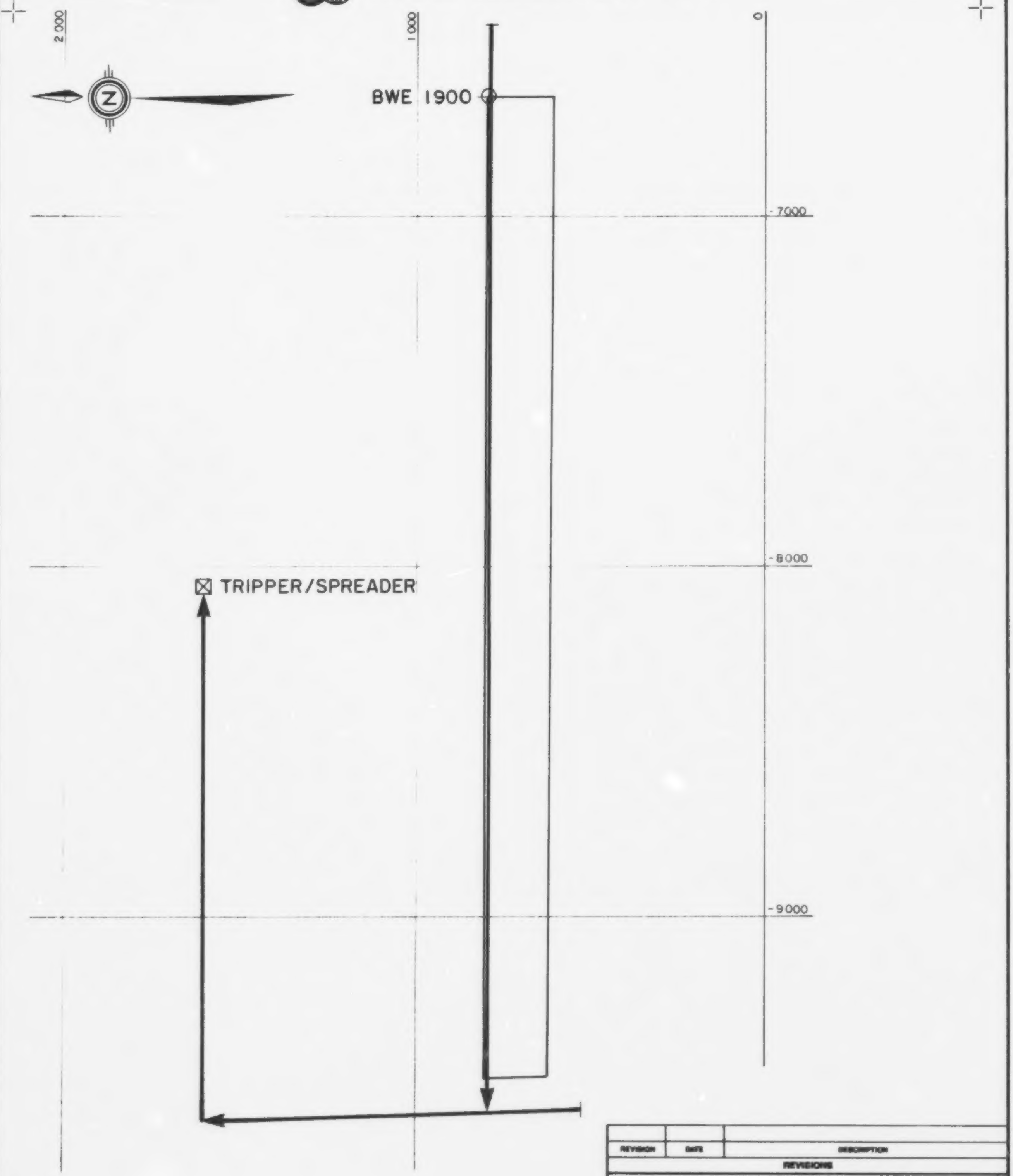
THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

MONENCO TEST CASE I
BLOCK MODEL AND CONVEYOR
CONFIGURATION

MONENCO LIMITED

1986-08-20 DATE | DSS 8291-8 003978 017 | FIGURE 4-3

MONENCO CONSULTANTS LIMITED


2 000
1 000
0
Z
BWE 1900
-7000
-8000
☒ TRIPPER/SPREADER
-9000

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

MONENCO TEST CASE 3
BLOCK MODEL AND CONVEYOR
CONFIGURATION

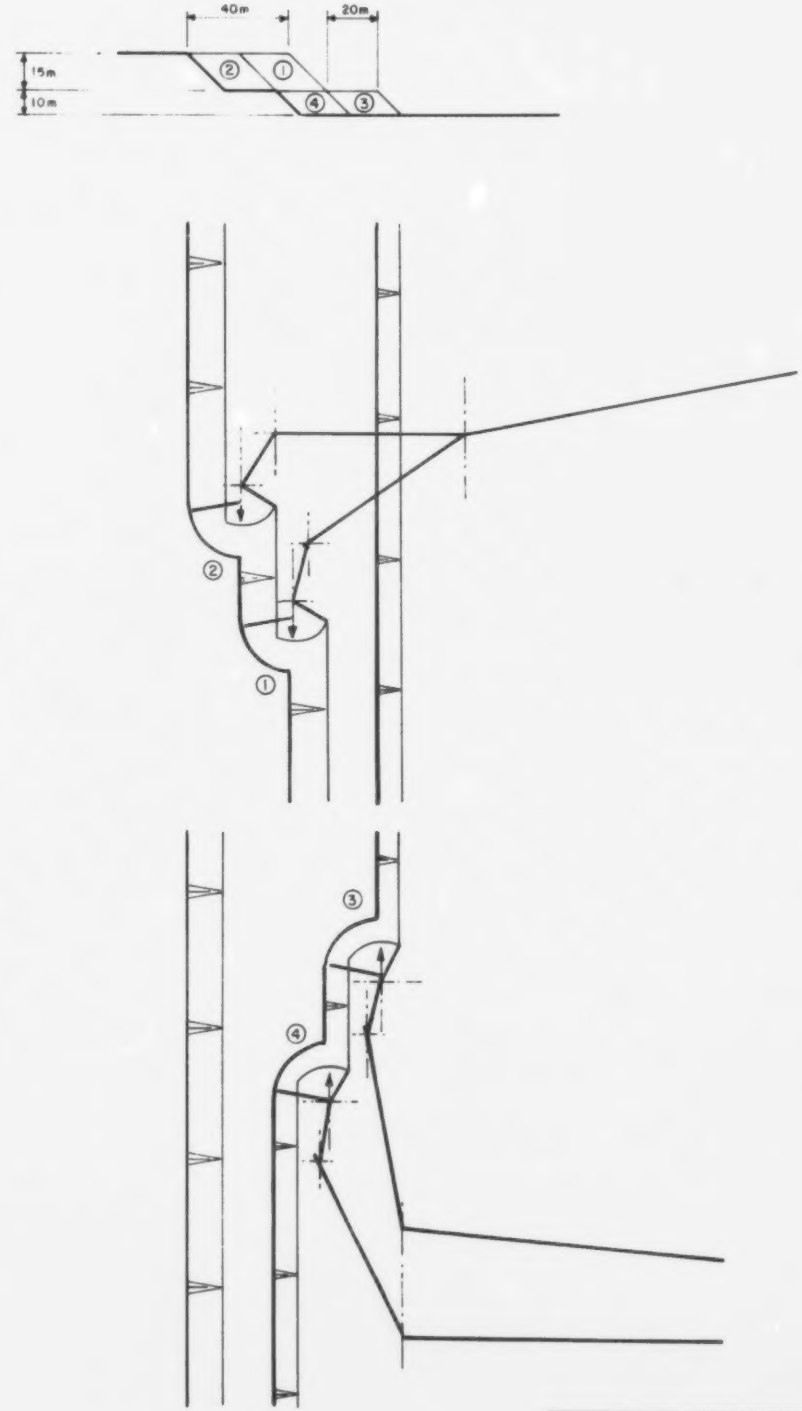
MONENCO LIMITED

1986-08-20
DATE

DSS 8291-8 003978 017

FIGURE 4-4

MONENCO CONSULTANTS LIMITED


40m
20m
15m
10m
②
①
④
③
②
①
③
④

0
50
100
150 METRES

REVISION	DATE	DESCRIPTION

REVISIONS

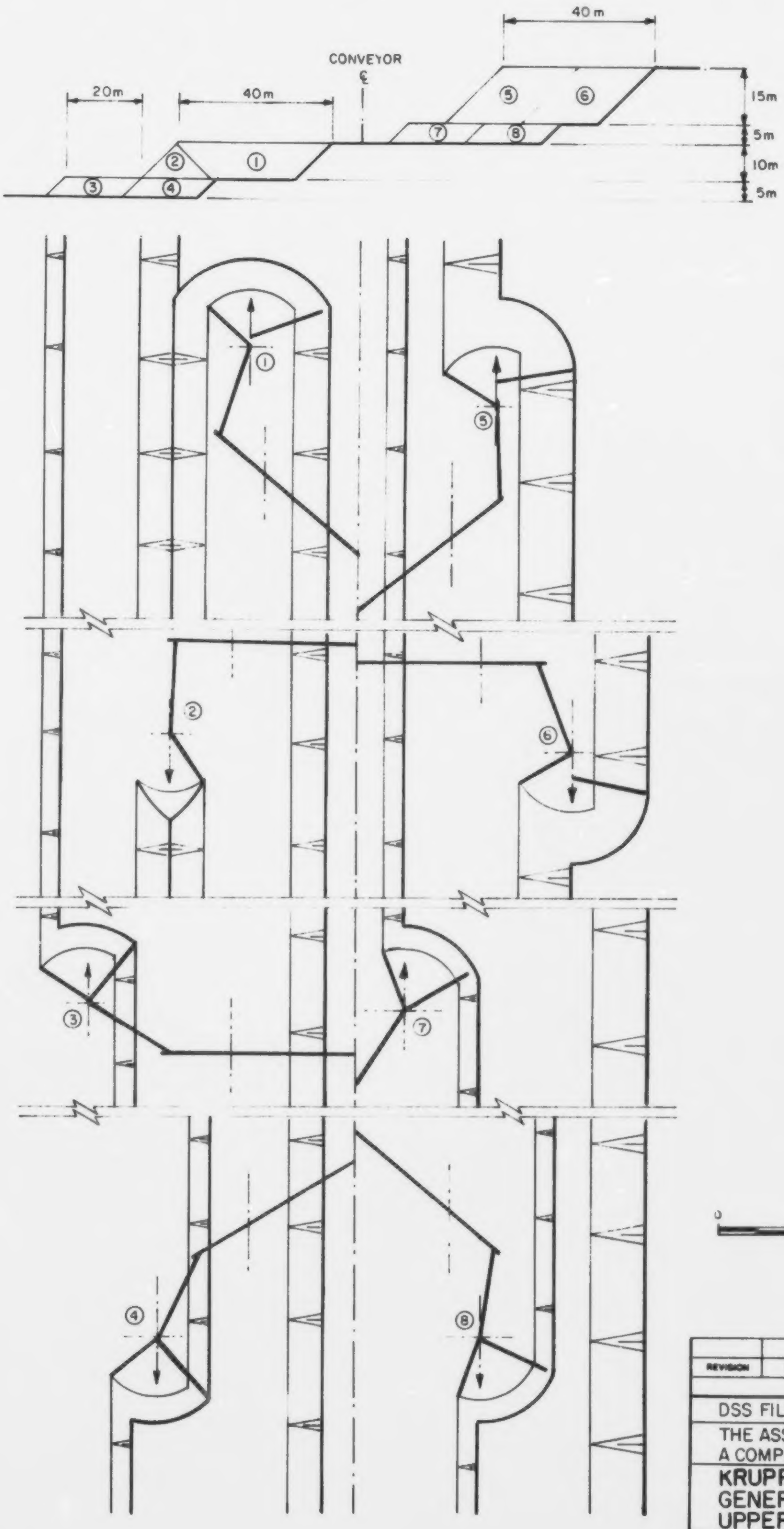
DSS FILE No. 03SQ 23440-5-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

KRUPP TEST CASES
GENERAL CUTTING DIAGRAM
LOWER SYSTEM

MONENCO LIMITED

1986-08-20 DATE | DSS 8291-8 WORK ORDER | 003978 BARCODE | 017 SYSTEM | FIGURE 4-6


40 m
CONVEYOR
℄
20m
40m
⑤
⑥
15m
⑦
⑧
5m
②
①
10m
③
④
5m
①
⑤
②
⑥
③
⑦
④
⑧

0
50
100 METRES

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF A COMPUTER BASED SIMULATION MODEL

KRUPP TEST CASES
GENERAL CUTTING DIAGRAM
UPPER SYSTEM

MONENCO LIMITED

1986-08-20 DATE	DSS 8291-8 003978 017 WORK ORDER SUBCODE SYSTEM	FIGURE 4-7

PART 5

CONCLUSIONS

5.0 CONCLUSIONS

5.1 OVERALL IMPRESSIONS

511 UNDERLYING THEORY

The bucket wheel excavator, conveyor and bin/hopper modules have been built with the goal of simulating the operations of the equipment to sufficient accuracy that they could be used for production monitoring. The required accuracy is achieved by modelling the equipment functions at their most detailed level, based upon the empirical formulae published mainly by the Conveyor Equipment Manufacturers Association and L. Rasper. These formulae have been well-proven in practice elsewhere and have been shown to yield reliable results when used within the boundaries of the experience on which they are based.

It is doubtful whether this precision is required when the equipment is used in a full operational environment. For example, it is possible when using Rasper to precisely calculate the length of time required to perform a slice. Yet reverse slew time, positioning time, operational efficiency and times for equipment breakdown are all arbitrary factors that the program user must enter. Cumulatively, the importance of these arbitrary factors on overall productivity is at least as great as the precise calculations that come from the empirical formulae.

Because of these uncertainties, a much simpler BWE model that employed distributions for "time to complete a slice", "reverse slew time" and "tramming time" would provide a result equally reliable to the current method, but with far less computational effort.

As for the conveyor model, we consider that for production monitoring the belt width and belt speed are known, and therefore belt capacity is either a known quantity or can be calculated from the CEMA formula. The mechanical and electrical availability of simple conveyor networks is so high that for short-term monitoring they can be considered as always available.

We have mixed feelings with regard to the appropriateness of using simulation methods to model what is essentially a continuous serial process. Simulation is more commonly used in two other situations: multiple runs through a serial continuous process in order to determine the distribution of possible outcomes, or for studies of queuing on a discrete process. Empirical formulae rather than statistical distributions are used for the parts of the BWE model most appropriate for simulation techniques. Nevertheless, we like the idea of using the simulation method if only because it forces the prospective program user to think about the ranges of possible outcomes - for example if a conveyor breaks down, how long it is likely to be unavailable.

512 DOCUMENTATION

Documentation should help the prospective user understand the way a program accomplishes its function, help the user to get the program to work using his own data and help the user when he gets into problems.

All three models that comprise the BWE-conveyor-bin/hopper model have documentation that clearly illustrates the theory that underlies the modules. While we have made numerous comments in Section 2 of this report, our overall impression of the documentation with respect to understanding the theory is very favourable.

The modules are less successful when it comes to helping the user to enter his data and get the program running. Two serious deficiencies are apparent: the formats for data files used by the bin/hopper and conveyor modules that are specified in the documentation is implied to be "free format". However, free format input will not work, and data must be entered precisely as shown in the supplied examples with commas separating all variables and at the end of each record, no internal spaces, and decimal points accompanying real-valued variables. There are neither warnings in the documentation nor internal data checks to ensure that the user's data lies within the acceptable limits to the empirical formulae and within the program dimensions.

The documentation does not have an "In Case of Difficulty" section for any module. Run failures that result in operating system messages are all too frequent, and even those program halts that are program-controlled are not described in the documentation.

A user who is not a competent FORTRAN programmer would be unlikely to get the simulator working on his own data.

513 OPERATION

As was shown in Part 4, we had considerable difficulty getting the simulator to work. There are numerous data files to prepare, and the formats of several of the files are less flexible than we would like to see. The BWE module has a useful input echo that the other modules could copy; the bin/hopper and conveyor modules have a useful debug facility that the BWE module could profitably use.

The means of specifying the geology and mining sequence to the simulator is awkward and needs revision. At the extreme, the layer specification dictates the operational method rather than the other way around.

The terminal display is good. The information that is displayed is useful and permitts adequate monitoring of the simulation. No changes are required.

The interrupt menus were seldom used. They appear generally adequate, but do not cover the very wide range of operational options that are possible. As one simple example, we cannot change from bench cut to drop cut in the middle of a run, yet if material digging resistance were to change along a bench it may be necessary to make the change. Nor were we able to add or delete the belt wagon in the middle of a run.

Two printouts are available. All movements of the bucket wheel excavator are recorded in FOR021.DAT. This printout is very useful. Status changes in the conveyor network or the bin/hopper are recorded in the main report PRINT.DAT when the appropriate debug switch is activated. The conveyor and bin/hopper status changes need to be output into FOR021.DAT.

PRINT.DAT is the main output report. The initialization echoes are adequate although we would like to see echoes of the conveyor and bin/hopper input data. These are available (although some have been converted) if the appropriate debug switch is activated. A graphical representation of the Weibull distributions would improve the user's confidence that they have been correctly specified.

There is no hourly BWE production report. Nowhere on the report does it indicate the volume of material that has passed through the bin/hopper. Otherwise, the hourly, shift, day and total reports are adequate.

The simulator was unable to handle the relatively simple operational procedure represented by Monenco Test Case 3. It is certainly incapable of handling the more complex Krupp Test Cases. Yet these are not unusual operational methods; the simulator, to be useful, must have far greater operational flexibility than it now possesses.

The bucket wheel module is unable to calculate mined volumes and operating hours correctly. The problem appears to be caused by an internal indexing problem hidden somewhere inside the code.

5.2 SUGGESTIONS FOR IMPROVEMENT

The following changes could be made to make the simulator more useful for overburden mining:

a) Delete all references to lateral cut method of mining;

b) Remove the concept of layers, and introduce a flexible bench height;

c) Delete all references to material grade;

d) Add tripper/spreader capability to conveyor model;

e) Make input files truly free format;

f) Delete all references to more than one piece of feeding equipment;

g) Delete the empirical CEMA and Rasper formulae; make them stand-alone programs useful for equipment sizing studies;

h) Replace Rasper formulae by statistical distributions that the program user can input;

i) Write an "In Case of Difficulty" section to the documentation;

j) Increase debug capabilities of the BWE module; add input echo to conveyor and bin/hopper modules;

k) Improve range of user-variable options available during the course of a simulation;

l) Make conveyors independently moveable, so that the belt wagon and stacker could be modelled as conveyors; and

m) Add capability to handle cable belt and high-angle conveyors.

These changes amount to a virtual re-writing of the entire BWE module, plus significant changes to the conveyor module. It is difficult to estimate how long it would take to make these changes, but as a very rough estimate two man-years could provide a tested product with moderate operational flexibility and user-friendliness.

5.3 CONCLUSIONS

There is a need in the Canadian mining industry for a product similar to the bucket wheel-conveyor-bin/hopper model. The most pressing need is for a product that will assist with equipment selection and selection of improved operating methods.

At present, a conveyor model would receive most use. Specific projects that may require evaluation are direct shovel loading of mobile crushers; permanent in-pit crusher stations; high-angle conveying out of pit; continuous underground mining machinery.

Suncor is the only Canadian mine that currently uses a bucket wheel excavator for mining in-situ overburden. TransAlta is considering the installation of a BWE-conveyor system for overburden removal at the Highvale Mine.

The NRC/CANMET simulator is not yet ready to fulfill this industry requirement.

The development of the BWE-conveyor-bin/hopper simulator was halted abruptly with the cancellation of the Canstar oil sands project in 1982. The simulator shows the effect of this abrupt termination. Certain portions of the code have in fact never been written, and the results that the simulator does achieve are not always correct.

Major revisions to the simulator, and particularly to the BWE module, will be required in order to make the simulator a product that is potentially useful to industry.

A comprehensive search needs to be made in the marketplace for alternative products prior to further investment in the NRC/CANMET simulator.

5.4 RECOMMENDATIONS

As presently constituted, the BWE-conveyor-bin/hopper simulator is not ready for use by Canadian industry. Considerable modification, especially to the BWE module, would be required in order for the simulator to be even partially effective for the short-term production monitoring that it has been designed to do.

Prior to making this investment, we recommend that CANMET conduct a worldwide survey to determine what products are currently available in the market that claim to satisfy either the short-range or longer-range needs of Canadian industry. If products are found, we recommend that they be evaluated against a pre-determined set of requirements, then the highest-ranking programs should be evaluated in a similar manner as the NRC-CANMET simulator.

We can recomend further investment in the NRC-CANMET simulator only if an exhaustive search of the world marketplace does not uncover a satisfactory alternative for short-range production monitoring. In that case there may be an advantage in rewriting the BWE module of the simulator rather than try to upgrade it.

APPENDIX A

LIST OF EXPERIMENTS RUN USING DEFAULT DATA

APPENDIX A

LIST OF EXPERIMENTS RUN USING DEFAULT DATA

CONVEYOR-BIN MODEL

Base Case:

a) Default data, except random seed in GASP.DAT changed to 12345. Result: the simulation hovered at SIMTIM=0 and had to kill run.

b) Default data, except random seed changed to 7. Result: simulation ran OK. Output file called BASECASE.DAT.

Experiment 1:

a) As Base Case, except speedup factor changed from 60 to 3600. Result: screen updated once per hour; total execution time much reduced; results close to, BUT NOT IDENTICAL WITH the base case results.

Experiment 2:

a) As Experiment 1, except angle of repose reduced to 33 degrees. Result: expected response, and basic equations check out OK. Slight error in documentation in units for cross-sectional area; result is in SQUARE INCHES.

Experiment 3:

a) As Experiment 1, except maximum conveyor speed reduced to 2.72 m/sec. Result: identical to Experiment 1.

Experiment 4:

a) As Experiment 1, except maximum conveyor speed reduced to 2.03 m/sec. Result: identical to Experiment 1.

Experiment 5:

a) As Experiment 1, except bin outflow increased to 1500 BCM/hr to eliminate the "bin full" condition part way through the run. Maximum conveyor speed further reduced to 1.34 m/sec. Result: no more bin overloads, but instead a few "bin empty" warnings; still no belt overloads.

Experiment 6:

a) As Experiment 5, with maximum belt speed 1.0 m/sec. Result: identical to Experiment 5.

Experiment 7:

a) As Experiment 5, with maximum belt speed 0.5 m/sec. Result: identical to Experiment 5.

Experiment 8:

a) As Experiment 5, except maximum belt speed 0.25 m/sec. Result: identical to Experiment 5.

Experiment 9:

a) As Experiment 5, except maximum conveyor speed returned to 4.06 m/sec. Increased idler separation from 1.219 up to 1.828 m. Result: Energy consumption went up; result checks with equations.

Experiment 10:

a) As Experiment 5, except maximum conveyor speed at 4.06 m/sec and capacity factor on Conveyors 1 and 2 reduced to 80%. Result: belt speed on Conveyors 1 and 2 drop because capacity is dropped. Equations check as long as we accept the restriction that capacity is an input, and speed the output. Somewhat less production delivered to bin because the slower belts have a larger inventory of material, and in cases of breakdown it takes longer to empty and refill belts.

Experiment 11:

a) As Experiment 10, except maximum belt speed also reduced to 2.72 m/sec. Result: identical to Experiment 10.

Experiment 12:

a) As Experiment 5, except maximum belt speed 4.06 m/sec. Belt width on Conveyors 1 and 2 reduced to 42 inches. Result: belt speed goes up in order to handle the input capacity. Production over Conveyor 2 is higher; other conveyors have identical production to Experiment 5.

Experiment 13:

a) As Experiment 10, except capacity factor reduced to 60%. Result: get lots of "overload trip" shutdowns on Conveyor 2 because reduced capacity is below the productive capacity of the feeding equipment. Total production into the bin is severely curtailed.

Experiment 14:

a) As Experiment 10, except belt speed reduced to 2.03 m/sec. Result: identical to Experiment 10.

Experiment 15:

a) As Experiment 5, except belt speed 4.06 m/sec. Head station of Conveyor 2 and both head and tail of #1 raised by 300 m to simulate a 15% upgrade on Conveyor 3. Result: production into bin unchanged; energy consumption of Conveyor 2 goes up by an amount consistent with a lifting efficiency of 87%.

Experiment 16:

a) As Experiment 5, except belt speed 4.06 m/sec. Conveyors 3, 4 and 5, and the tail of Conveyor 2 all raised 300 m to simulate a 15% downgrade on Conveyor 2. Result: production into bin unchanged; output conversion error on initialization echo of Conveyor 2 grade; negative energy consumption on Conveyor 2 consistent with a lowering efficiency of 92%.

Experiment 17:

a) As Experiment 5, except belt speed 4.06 m/sec. Wrap reduced to 180 degrees; operator alert for empty conveyor reduced to 90 minutes. Result: power requirements significantly reduced; no change in production.

Experiment 18:

a) As Experiment 17, except changed speedup factor to 86400 (1 screen update per day) and number of shifts to 1092 (1 year). Changed maximum repair time for a mechanical breakdown on the conveyor to 4320 (72 hours) to correspond to the time required to splice a belt tear. Result: required approximately 50 seconds to simulate the events of a full day. A significant portion of this time spent on screen update; was running at 1200 baud. Began running into an output conversion error at SIMTIM=691200 and terminated run at SIMTIM=777600 because format errors were so frequent that processing had slowed to a crawl. The output report cannot not handle 10000 or more minutes of operating time.

BWE-CONVEYOR-BIN MODEL

Experiment 19:

a) Ran model using default data. Got mixed up on specification of benches and assigning BWE to benches so program aborted.

b) Ran model using default data. Job ran normally. Result: output conversion error caused by format overflow on conveyor move time in input echo. Noted lack of hourly report for BWE production; screen display indicates both BWE are operating on same block; liked the echo of input parameters and the system operation notes (though could not interpret code (e.g. B/H F.C.); liked the event history file FOR021.DAT. Report indicates that both machines are mining the same block at the same time, but no error message given. Problem caused by error assigning BWEs during interactive session.

Experiment 20:

a) Made these changes to the data files: TUPM=3600, IHISFL=1, HROFST=8, CONVMT=48, Bin Capacity=60000, Bin Outflow=5000, Speedup=3600, Speed=7, Empty Belt Warning=90. New block geometry: DX=60.00, DY=50.00, X1=15118, Y1=18359, Z1=290, X2=15718, Y2=18359, Z2=290, X3=15118, Y3=18859, Z3=300, X4=15718, Y4=18859, Z4=300.

Block geometry of Bench #2: DX=60.00, DY=50.00, X1=14965, Y1=17749, Z1=270, X2=15565, Y2=17749, Z2=270, X3=14965, Y3=18249, Z3=290, X4=15565, Y4=18249, Z4=290.

Result: BWE 1300 assigned to Bench Cut; BWE 1301 to Drop Cut. This time we seem to have each machine on its own bench. See table below Experiment 22 for results.

Experiment 21:

a) As Experiment 20, except BWE 1300 assigned to Drop Cut, and BWE 1301 to Combination Cut. See table below Experiment 22 for results.

Experiment 22:

a) As Experiment 20, except BWE 1300 assigned to Combination Cut, and BWE 1301 to Bench Cut. Responded YES to the question concerning "change any input data?", though actually did not make any changes.

Result: Output conversion error because BWE ID can only be 3 characters long. Otherwise, see table below.

RESULTS OF EXPERIMENT 20-22

	Vol. Produced	Digging Hours	Boulder Hours	Other Hours	Breakdown Hours	Productivity Per Oper. Hour	Productivity Per M.A. Hour
BWE 1300							
Combination	9531	6.04	0	0.51	1.45	1578	1455
Bench	14167	6.07	0	0.48	1.45	2334	2163
Drop	10123	6.10	0	0.45	1.45	1660	1545
BWE 1301							
Combination	15826	6.68	0.32	0.85	0.15	2369	2016
Bench	19422	6.70	0.40	0.75	0.15	2899	2474
Drop	14141	6.47	0.43	0.95	0.15	2186	1801

While the Bench Cut is always the most productive method of operation, the difference between Drop Cut and Combination Cut is not consistent. The downtime due to repositioning the machines ("Other Hours") is also not consistent, and the boulder delays incurred by BWE 1301 look anomalous while on Combination Cut.

Experiment 23:

a) As Experiment 22. Result: Identical to Experiment 22 in every detail. Can conclude that the results of Experiment 20 and Experiment 21 are reproducible.

Experiment 24:

a) As Experiment 20, but shortened block length to 6.0 m and increased length of run to 3 shifts. Ran both machines in Bench Cut mode. Result: Program crashed on ACCESS VIOLATION - EVENT 101 - "START OF A SLICE CUT" - at Line 91.

b) Added data to SEQ.DAT for 2 additional sections for each bench, then re-ran program. Result: Same program crash after 3 hours of operation.

Experiment 25:

a) As Experiment 24, but lengthened blocks to 16 m and ran for 3 shifts using Drop Cut. Result: Program ran, but run was plagued by extensive breakdowns to both BWE. Screen display indicated both BWE reached blocks (1, 2, 3) on both benches.

Volume per layer = 3656 m^3
Block (1, 2, 3) = 10 Steps = 36560 m^3
Report indicates BWE 1300 production = 32553 m^3
BWE 1301 production = 41844 m^3
Seems to be a mismatch here.

Experiment 26:

a) As Experiment 24. Changed breakdown frequency BOTDST in DIST.DAT to 96000 96000 24000 288000; also reset warning for empty conveyor back to 9000 mins. Ran both machines in Drop Cut mode. Result: Simulation ran to end, but both machines seemed to be stuck at block (1, 2, 8) for a long time.

Volume per layer = 1371 m^3
Block (1, 2, 8) = 30 steps = 41130 m^3
Report indicates BWE 1300 production = 42862 m^3
BWE 1301 production = 42099 m^3
Volumes look pretty good!

Experiment 27:

a) As Experiment 26, except changed X2=X4=15025 so that everything is consistent within DDBASE.DAT. Result: Identical to Experiment 26.

Experiment 28:

a) As Experiment 26, except block length changed to 60 m. Ran Drop Cut mode for 3 shifts. Result: Simulation moved quickly to block (1, 2, 1) at 11:00:00 and stayed there for remaining 21 hours of run. Printout has VAX system error "DEVICE TIMEOUT, ERROR WRITING TXA1:" so do not have production statistics after 21:00:00.

Volume per layer = 13710 m^3
Block (1, 2, 1) = 2 steps = 27420 m^3

Experiment 29:

a) As Experiment 26, except block length changed to 12 m. Renamed SEQ.DAT to SEQ.OLD and made a new file SEQ.DAT with only 3 columns per section. Changed NX=3 in DDBASE.DAT. Order of mining is:

SECTION	LAYER	COLUMN
1	1	1
1	2	1
1	3	1
1	4	1
1	1	2
1	2	2
1	3	2
1	4	2
2	1	1
2	2	1
2	3	1
2	4	1
1	1	3
1	2	3
1	3	3
1	4	3
2	1	2
2	2	2
2	3	2
2	4	2

This sequence was made to try to simulate a double-benching method similar to what will be used in the Monenco test case. Ran BWE 1300 only in Drop Cut mode. Result: Output conversion error into PRINT.DAT because bin is always empty. Message appeared on screen (display showed at (1,4,2):

```
'BWE 1300 has reached end of Section #1
 If you wish (sic) to alter section moves as set up enter "1"
 If you don't want a change, enter "2"'
```

After entering "2", dialogue continued:

```
'Request for conveyor 1 to move
      X incr = 1261
      Y incr = 50
      Move now?  1 = Yes   0 = No'
```

Run continued after entering "0" but no subsequent production; screen displayed showed BWE either on idle or breakdown. BWE production was 3994.6 BCM; conveyor report shows 3986 BCM.

Experiment 30:

a) As Experiment 28. Renamed SEQ.DAT to SEQ.NEW and copied SEQ.OLD to SEQ.DAT. Edited SEQ.DAT so that except for having 10 columns rather than 3 both BWE 1300 and BWE 1301 looked identical to SEQ.NEW. Result: Same error as Experiment 24: "2 Cases where there are a different number of layers than this sequence calls for".

Experiment 31:

a) As Experiment 29, except ran simulation for 3 days. Result: 4 hours into shift, received "end of Section #1" message. Display showed simulation at Block (1, 4, 2) with 4349 BCM delivered to plant.

Volume per layer = 2742 BCM
Block (1, 4, 2) = 8 steps = 21936 BCM

Therefore seems to be a great discrepancy between block volume and simulated production.

Immediately thereafter, got lost in all the interactive menus.

1) Do you want to alter section moves? (entered "0")
2) Menu with 9 items:
   1 delete PM
   2 start PM
   3 standby
   4 bring BWE off standby
   5 walk to new locn
   6 walk to intermediate locn
   7 wait, then walk
   8 stop BWE
   9 start BWE
   (entered "6")

3) "The following are the sequences that have been mined for BWE #*** (output conversion error)

```
     SEQ#     LAY#     COL#
```

How many new blocks would you like to mine now?"
(entered the series of blocks that followed (1, 4, 2) in SEQ.NEW)

4) Returned to 9-item menu
(entered "9")

5) Stuck at this menu
(entered "return")

6) "Model terminated due to completed blocks"

Experiment 32:

a) As Experiment 29, except copied SEQ.OLD to SEQ.DAT, and edited SEQ.DAT to go back to 10 columns in the single-cut digging pattern. NX=10 and NY=2 in DDBASE.DAT. Ran simulation for 21 shifts. Result: Interactive session will not accept 21 shifts; 20 shifts is OK. Display quickly moved to Block (1, 2, 4) and stayed there although tonnes to extraction plant kept going up through the run. Expected end of cut to be reached at 109680 BCM, but at end of run had apparently delivered 364395 BCM to extraction plant without ever reaching the end of section or initiating any conveyor moves.

Printout has VAX system error "DEVICE TIMOUT, ERROR WRITING TXA1" so do not have production statistics after 16:00:00 of first day.

Experiment 33:

a) As Experiment 32, except edited SEQ.DAT to make only 1 layer. NZ=1 in DDBASE.DAT. Result: "There are 12 blocks that don't correspond with sequence numbers".

b) Edited DDBASE.DAT to eliminate raw data for layers 2-4. Result: Almost immediately (FOR021.DAT says at 8:32:33), with display still at (1, 1, 1) received message "end of Section #1". Entered "2"; terminal responded:

```
X incr = 2603
Y incr = 120
Move now?
```

Entered a 1 minute move time, and simulation continued. Display moved to (1, 1, 4) with BWE on idle to end of simulation run.

APPENDIX B

LIST OF EXPERIMENTS RUN USING MONENCO TEST CASE 1

APPENDIX 2

LIST OF EXPERIMENTS RUN USING MONENCO TEST CASE 1

Experiment 34:

a) Prepared data files for Monenco Test Case #1. The area covered by this test case is shown in Figure 4-1 and the details of the required mining sequence are shown in Table 4-1. The data files that contain all the necessary conveyor and bucketwheel specifications are shown in Appendix Tables 2-1 to 2-5. These were entered using free format as indicated in the documentation. Our interpretation of the way DDBASE.DAT, SEQ.DAT AND PITCHG.DAT must be structured to duplicate the proposed mining system are shown in Tables 2-6 to 2-8.
Result: program crashed several times due to "invalid text" errors in CONVEY.DAT.

b) Referred to source code of INITIA.FOR and noted that data are read in fixed format. Editted CONVEY.DAT to match format specifications of INITIA.FOR.
Result: program crashed due to "invalid text" error in CONVEY.DAT.

c) Edited CONVEY.DAT to add commas between all variables and remove all blanks between variables. This results in a data file similar in appearance to the default data files, but is neither "fixed format" nor "free format".
Result: "undefined exponentiation" error in INITIA.FOR at line 97.

d) Set switches 6, 42 and 45 to "1" in INPOUT.DAT. Loaded all source code onto computer from tape back-up. Determined that this new problem had to be due to CNSTAT.DAT. Deleted spaces and added commas to CNSTAT.DAT. Also added some decimal points to variables in CONVEY.DAT.
Result: "invalid text" error.

e) Edited CNSTAT.DAT to put commas as last character in each record; added decimal points to all parameter values.
Result: "undefined exponentiation" error at line 77 of W2.FOR.

f) Edited CNSTAT.DAT so that electrical breakdown value was "1920." rather than "192.".
Result:

```
Restart file no.                            (entered (CR))
Do you want to initialize conveyor network? (entered 0)
Do you want initialization reports?         (entered 1)
```

Program crashed while trying to read "E" format in BIN.DAT.

g) Made several changes in BIN.DAT to make format similar to the format of the default data.
Result:

# Shifts	(entered 3)
Do you want initialization reports?	(entered 1)
Do you want shift reports?	(entered 1)
Do you want shift reports?	(entered 1)
# Benches	(entered 1)
# BWE	(entered 1)
# BWE on Bench #1	(entered 1)
Field ID of BWE #1	(entered 1900)
Type of cut	(entered 3)

Program crashed due to "read in error from BWE.FILE(SEQ)".

Experiment 35:

a) Noted that somewhere along the way SEQ.DAT had become a copy of ATRIB.DAT, so brought back the original version of SEQ.DAT. Edited ATRIB.DAT to add decimals and commas and remove spaces.
Result: "There is/are 1 case where there are a different number of layers than this sequence calls for".

b) Examined source code of READIN.FOR and noted that the program seems to be dimensioned for a maximum of 120 steps. Edited SEQ.DAT to remove the fourth section. This leaves approximately 100 steps in 3 sections.
Result: "There are 3 blocks that don't correspond with sequence numbers".

c) Continued to examine READIN.FOR and noted that in a zeroing loop the variable BLOCK is apparently dimensioned for 2 sections, 5 layers and 10 columns. Edited DDBASE.DAT and SEQ.DAT to make the new files have 2 sections, 5 layers and 10 columns. Did not change coordinates or block dimensions.

Result:

Desire to change sequences?	(entered N)
Desire to change BWE attributes?	(entered N)

"Invalid argument to math library" in line 281 of CALBLC.FOR.

d) Edited CONVEY.DAT to remove decimals from coordinate specifications and added commas and removed spaces from the initialization section of CONVEY.DAT.
Result: same error as Experiment 35(c), but examination of PRINT.DAT indicated conveyor initialization is now OK.

Experiment 36:

a) Found that layer thickness (5 m) and block length (200 m) were reversed in DDBASE.DAT.
Result: program crashed because "the bench is too high for the BWE parameters. The boom hits the top edge before mining anything".

b) Examined CALBLC.FOR. Found buried inside the code the restriction:

Hinge height   (N-1) * Layer thickness
where: N = Number of layers in bench

In Monenco test case #1, the BWE has a hinge height of 18.0 m, layer thickness is 5.0 m and there are 5 layers, so the program fails on this test.

Revised DDBASE.DAT so that layer thickness = 6.0 m and number of layers = 4. Removed all references to layer #5 from DDBASE.DAT and SEQ.DAT.

Result:

```
Do you want periodic conveyor reports?      (entered 1)
Do you want periodic bin/hopper reports?    (entered 1)
Do you need display?                        (entered 1)
Do you want extraction file?                (entered 0)
```

Screen then switched to the production monitor mode.

Output conversion error due to maximum bin capacity of 99999 LCM. Normal termination, but noted the BWE statistics showed machine was digging at block (1,3,4) at production rate 2295 bcm/hr but conveyors were empty, no material into bin and no material delivered to extraction plant.

Although material was classified as "waste", FOR021.DAT indicated status code was "digging in ore". Status changes as soon as simulation begins.

Experiment 37:

a) Edited BIN.DAT to make capacity 99999 and outflow 10000. Time between blockages reduced to 600,10,590,900.
Edited X1, Y1 of DDBASE.DAT to -7290,2050 to precisely agree with conveyor loading point.
Result: program ran to completion but still no production onto conveyors. PRINT.DAT shows error "Invalid Feeder Device 101___".

b) Noted that conveyor initialization report does not indicate any grade (%). Referred to the default data reports and noted that they also have an incorrect grade value.
Edited DIST.DAT to make time to repair tooth 240,240,30,480 and time between tooth delays 6000,100,5000,7000.
Edited DDBASE.FOR to make summer dig resistance 120 kg/cm and winter dig resistance 150 kg/cm.
Result:

```
"One of the blocks for bench #1 sec 1 layer 1 col 1 has a
slice time of 0...impossible

top cut slice time = -0.09 mins
bench cut time     = -0.09 mins
cut type #         = 3"
```

d) Edited ATRIB.DAT to change wheel radius from 13.0 to 6.5 m. Noted that the code for ore conveyor device # was missing so added "1". Returned summer and winter digging resistance to former value.
Result: program ran to completion, but still no production into conveyors. PRINT.DAT contained error message:

```
"Error in new feeder location
2 0 0 0 -7290 2050 18 -6690 0 0 2300 0 0"
```

e) Edited CONVEY.DAT so that conveyor #1 runs exactly east-west.
Result: identical to Experiment 37(d).

f) Edited INPUT.DAT to turn on debug switches 41, 45 and 48. Examined source code for EVT301.FOR. Deduced that block model must be set up with X2 a positive increment from X1. Edited DDBASE.DAT so that X1 = -7890. First block mined is column 4, so that conveyor load point = -7890 + 600 = -7290.
Result: program ran to completion and belts loaded, but BWE became idle right away and nothing delivered to the bin.

Experiment 38:

a) Edited BIN.DAT, CONVEY.DAT and DDBASE.DAT to make the negative eastings into positive westings (i.e. all coordinates are positive). Reduced outflow from bin to 1000 LCM.
Result: program ran to completion, but at 12:20:48 BWE came off repair and immediately got overload trip on conveyor #1. BWE remained on idle for rest of simulation.

b) Edited CNSTAT.DAT to change the time between conveyor trips to 9600,9600,600,28800. Edited INPUT.DAT to turn on debug switch 50.
Result: identical to Experiment 38(a).

c) Reran Experiment 38(b), trying the interactive menu to force the BWE back into position, but production stopped immediately each time due to overload trip.

Experiment 39:

a) Edited CONVEY.DAT to set maximum conveyor capacity at 14071 from 4071.
Result: program ran to completion with no overload conditions. Screen output shows that prior to 12:20:48 BWE production is 1646 bcm/hr; after 12:20:48 production is 3292 bcm/hr. Overload had been caused because 3292   68% of 4071.

Experiment 40:

a) Returned time between conveyor trips to 960,960,60,2880 in CNSTAT.DAT. Edited INPOUT.DAT to turn off debug switches 41, 42, 47, 48 and 50. Ran program for 21 shifts with no bin/hopper reports and conveyor reports each shift.
Result: production capacity cycled irregularly between 1646 and 3292 bcm/hr. After terminal indicated production had been at (1,4,10) for some time, message appeared:

```
If you wish to alter section moves as set up enter 1
If you don't want a change enter 2            (entered 2)
```

Message appeared on screen that conveyor 1 was being moved; BWE remained either on idle or under repair to end of run.

Output conversion error for conveyor working minutes on total report.

Block volume = 45 x 200 x 6 = 54,000 bcm
# Blocks mined in Section 1 = 14 x 54,000 = 756,000 bcm
Volume mined by BWE = 150,093 bcm
Volume delivered across Conveyor 3 = 149,850 bcm

Note discrepancy between theoretical and actual volumes.

Experiment 46:

a) Edited CONVEY.DAT to increase the time at which a conveyor must run empty before warning the operator to 1000. Changed bin outflow rate to 2250 lcm/hr in BIN.DAT; changed conveyor move time to 8 hours in ATRIB.DAT; increased maximum time between BWE mechanical breakdowns to 3840 mins in DIST.DAT. Ran program for 42 shifts with no bin/hopper reports and with conveyor reports each shift.
Result: similar to Experiment 40. Mining ended on section 1 at (1,4,10) at 2:17:24, and resumed on section 2 at (2,3,10) at 10:17:24. Run ended when all blocks in the sequence file were gone.

Block volume = 45 x 200 x 6 = 54,000 bcm
# Blocks in sequence file = 31 x 54,000 = 1,674,000 bcm
Volume mined by BWE = 247,401 bcm
Volume delivered across Conveyor 3 = 247,017 bcm

Note tremendous discrepancy between theoretical and actual volumes!

Conveyor move occurred during the 9th shift
Volume in Section 1 = 14 x 54,000 = 756,000 bcm
Volume mined by BWE to shift #9 = 150,093 bcm
Volume delivered across conveyor #3 to shift #9 = 149,847 bcm

These values are identical to the production recorded during Experiment 40.

At the theoretical production rate of 2,700 bcm/hr for the type 1900 BWE, it should require 280 operating hours to complete Section 1, and 620 operating hours for both sections. The results of Experiment 40 show an average dig rate of 2617 bcm/hour, but only 57.4 operating hours to complete Section 1. Experiment 46 indicates an average digging rate of 2531 bcm/hr and 97.7 hours to complete mining both sections.

Table B-1

BIN.DAT

```
1 7
1
1 2 3 4 5 6 7
5 1.0E+10 10000 100 99 -8790 2860 1 1
1 3 7 30 9 0 0 0 0 0
4
11 1 1 1 2                            / DURATION OF BLOCKAGE
12 600000 1000 590000 900000          / TIME BETWEEN BLOCKAGES
13 1 1 1 2                            / DURATION OF BREAKDOWN
14 600000 1000 590000 900000          / TIME BETWEEN BREAKDOWNS
```

Table B-2

CNSTAT.DAT

```
2,3,16,
1,1,2,2,2,2,2,2,
2,3,3,3,3,4,4,4,
6,
480.,480.,240.,2800.,       / TIME BETWEEN MECH B'DOWNS  (4F10.2)
30.,30.,15.,4320.,          / TIME TO REPAIR MECH BREAKDOWN
1920.,1920.,960.,11520.,     / TIME BETWEEN ELEC BREAKDOWNS
120.,120.,60.,1920.,        / TIME TO REPAIR ELEC BREAKDOWN
960.,960.,60.,2880.,        / TIME BETWEEN CONVEYOR TRIPS
5.0,1.5,2.0,15.,              / TIME TO RESET AFTER TRIP
```

Table B-3

CONVEY.DAT

```
30 35
240   15.24  0.8  15
5.0   0.91   0.2  0.8
3     1.0    480
4071  70.86  35.5  -9590  2060  736  -6820  2045  743  1  68  W
4071  70.86  35.5  -9615  2870  754  -9580  1790  736  1  68  N
4071  70.86  35.5  -8790  2860  757  -9615  2870  754  1  68  E
1  0  0  0  0  0  1  1  3  2  0  2300  0  0  -7290  2050
1  0  0  0  0  0  3  1  3  3  0   810  0  0  -9590  2060
1  0  3  2  0  0  0  0  4  1  0     0  0  0      0     0
1
1  3  3  3  4
1  1  2  3  1
```

Table B-4

ATRIB.DAT

```
0  18.7  0.08  1.0              / CUTCRD, CONVMT, REVSLT, SEAFAC
15  225  1  0  213              / ITIMPM, INTPM, ISEAFL, BLSTRE, COSTOP
12.0  8  1.1  1  3600           / RESMAX, HROFST, WCAKFC, IHISFL, TUPM
3  0  0  1  5.5  0              / CLENTM, NCOMB, IATTEN, JPAUSE, SLOTIM, IDISFL
700                             / BWE ID #
2  1  1                         / STATUS, DEVICE FOR ORE, DEVICE FOR WASTE
1  12  7.7                      / FEEDER FLAG, # BUCKETS, WHEEL RADIUS
16.0  1.2   8.0                 / BOOM LENGTH, BUCKET WIDTH, HINGE DIST
0.7  10.0  0.9                  / BUCKET CAPACITY, CRAWLER SPEED, OPERATOR EFF.
370.0  1.4  0                    / BELT LENGTH, BELT WIDTH, # PRECUTTERS
1.2  0  0                       / BUCKET LENGTH, KNIFE FLAG, # TEETH
320000  4.5  0.05               / STRUCTURE WEIGHT, BALL RACE DIAM, COEFF FRICT.
4.8  5.2  2                     / HOR DIST, FORWARD DIST, BELTWAGON FLAG
93.0  4.2  0.80                 / BELT WT, BELT SPEED, MOTOR EFF.
0.035  0.15  2                  / BELT COEFF FRICT, ROLLING RESIST, TOTAL RESIST
1                               / OUTPUT DEVICE NUMBER
```

Table B-5

DIST.DAT

```
       1.0       .01       0.99      1.01  / BOULDER DELAYS
       1.0       .01       0.99      1.01  / WASTE-FEED CHANGEOVER TIME
     240.0     240.0       30.0     480.0  / TIME TO REPAIR TOOTH
    6000.0     100.0     5000.0    7000.0  / TIME BETWEEN TOOTH DELAYS
  1900
       1.0       0.6        0.5       1.5  / SLICE TIME
     240.0     240.0       30.0     960.0  / TIME TO REPAIR MECH BREAKDOWN
     960.0     960.0      240.0    3840.0  / TIME BETWEEN MECH BREAKDOWN
    1440.0    1440.0      480.0    4320.0  / TIME TO REPAIR ELECT BREAKDOWN
    5660.0    5660.0      960.0   17280.0  / TIME BETWEEN ELECT BREAKDOWN
99999999999999999999999999999999999999999
```

Table B-6

DDBASE.DAT

```
 1
     45.00        5.00      200.00    -6890.00     2050.00      743.00
  -9490.00     2060.00      736.00    -6890.00     1870.00      743.00
  -9490.00     1880.00      736.00        4.00        5.00       13.00
     60.00        0.00        0.00
 1  1  1  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  1  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  1  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  1  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  1  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  2  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  2  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  2  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  2  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  2  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  3  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  3  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  3  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  3  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  3  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  4  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  4  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  4  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  4  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  4  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  5  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  5  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  5  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  5  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  5  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  6  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  6  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  6  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  6  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  6  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  7  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  7  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  7  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  7  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  7  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  8  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  8  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  8  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  8  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  8  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1  9  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2  9  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3  9  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4  9  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5  9  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1 10  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2 10  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3 10  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4 10  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5 10  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  1 11  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  2 11  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  3 11  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  4 11  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
 1  5 11  0.00  0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
```

Table B-6 (cont'd)

1	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00

Table B-6 (cont'd)

2	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00

Table B-6 (cont'd)

3	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	3	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	4	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
4	5	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00

Table B-6 (cont'd)

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    4   1   9   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   2   9   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   3   9   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   4   9   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   5   9   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   1  10   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   2  10   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   3  10   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   4  10   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   5  10   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   1  11   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   2  11   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   3  11   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   4  11   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   5  11   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   1  12   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   2  12   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   3  12   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   4  12   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   5  12   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   1  13   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   2  13   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   3  13   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   4  13   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
    4   5  13   0.00   0.002200.00   7.00   9.00  40.00   0.01   2.00   3.00
99999
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Table B-7

PITCHG.DAT

```
1   1
1   2
```

Table B-8

SEQ.DAT

```
 1900
1  5  3
1  3  4
1  4  4
1  5  4
1  1  5
1  2  5
1  3  5
1  4  5
1  5  5
1  3  6
1  4  6
1  5  6
1  3  7
1  4  7
1  5  7
1  3  8
1  4  8
1  5  8
1  4  9
1  5  9
1  4 10
1  5 10
1  3 11
1  4 11
1  5 11
1  3 12
1  4 12
1  5 12
1  3 13
1  4 13
1  5 13
2  3 13
2  4 13
2  5 13
2  3 12
2  4 12
2  5 12
2  3 11
2  4 11
2  5 11
2  3 10
2  4 10
2  5 10
2  3  9
2  4  9
2  5  9
2  3  8
2  4  8
2  5  8
2  3  7
2  4  7
2  5  7
2  3  6
2  4  6
2  5  6
2  1  5
2  2  5
2  3  5
2  4  5
```

Table B-8 (cont'd)

2	5	5
2	2	4
2	3	4
2	4	4
2	5	4
2	5	3
3	5	3
3	1	4
3	2	4
3	3	4
3	4	4
3	5	4
3	1	5
3	2	5
3	3	5
3	4	5
3	5	5
3	3	6
3	4	6
3	5	6
3	3	7
3	4	7
3	5	7
3	3	8
3	4	8
3	5	8
3	3	9
3	4	9
3	5	9
3	3	10
3	4	10
3	5	10
3	2	11
3	3	11
3	4	11
3	5	11
3	3	12
3	4	12
3	5	12
3	4	13
3	5	13
4	4	13
4	5	13
4	2	12
4	3	12
4	4	12
4	5	12
4	1	11
4	2	11
4	3	11
4	4	11
4	5	11
4	2	10
4	3	10
4	4	10
4	5	10
4	2	9
4	3	9
4	4	9
4	5	9

Table B-8 (cont'd)

```
    4  3  8
    4  4  8
    4  5  8
    4  3  7
    4  4  7
    4  5  7
    4  3  6
    4  4  6
    4  5  6
    4  2  5
    4  3  5
    4  4  5
    4  5  5
    4  1  4
    4  2  4
    4  3  4
    4  4  4
    4  5  4
    4  5  3
999999999
```

APPENDIX C

LIST OF EXPERIMENTS RUN USING MONENCO TEST CASE 3

APPENDIX C

LIST OF EXPERIMENTS RUN USING MONENCO TEST CASE 3

Experiment 41:

a) Dr. Chan prepared new version of program with dimensions expanded to 1000 steps, 10 sections, 10 layers and 20 columns.

Prepared the data files for Monenco Test Case 3. The area covered by this test case is shown in Figure 4-3. The details of the required mining sequence are shown in Table 4-2.

The data files that were originally prepared for this test case are shown in Tables 3-1 to 3-8. Before running this test case they were modified to match the data files used in Test Case 1.

In order to satisfy the program restriction found in Experiment 36(b), changed number of layers to 5, layer height to 6 m and hinge height to 24.0 m. This means that both the BWE and the geology model no longer represent the actual test case conditions.

Result: still required several runs to overcome format errors in the input data.

b) Made all required format changes to input data and tried again. Result: program "hung up" in an endless loop immediately after the question "do you want initialization reports" and immediately before the echo of the mining sequence would appear in PRINT.DAT.

c) i) Removed second bench data from SEQ.DAT.
ii) Reduced number of steps in SEQ.DAT down to 99 steps.
iii) Removed second bench data from DDBASE.DAT.
Results: program hung up in same endless loop.

d) Replaced the new version of the program with the version used during Test Case 1.
Result: program proceeded past the spot of earlier failure, then crashed because dimensions exceeded.

Experiment 42:

a) Restored the versions of SEQ.DAT and DDBASE.DAT used in Experiment 41(b). Edited both benches of data to maxima of 2 sections, 5 layers, 10 columns and 117 steps.
Result:

```
"Number of benches?                              (entered 2)
 Number of BWE?                                  (entered 1)
 There are more benches than BWE to assign.  Some benches
 will not have BWE assigned to them.
 How many BWE assigned to bench #1?              (entered 1)
 Field number                                    (entered 1900)
 Type of action                                  (entered 3)
 1 BWE assigned to the first bench(es).  You have no more
 BWE to assign.
 There are/is 1 bench(es) without assigned BWEs"
```

After the rest of the interactive prompts, program ran successfully for 1 shift.

b) Edited INPOUT.DAT to turn off most debug switches. Changed bin outflow to 2000 lcm/hr.

Edited SEQ.DAT to make each section only 4 columns long. Each block takes approximately 20 operating hours, so at 20 steps/ section will take 400 operating hours or approximately 70 shifts for BWE to mine each section.

Ran program for 150 shifts.

Result: program executing, but screen stuck at (1,5,1) with no production indicated.

c) Tried again for 3 shifts.
Result: program ran successfully.

d) Tried again for 21 shifts.
Result: program ran successfully but terminal display cycled between blocks (1,3,2), (1,3,3) and (1,3,4).

Experiment 43:

a) Reduced SEQ.DAT to 3 columns:

Bench #	Section #	# Steps
1	1	9
1	2	10
2	1	1
		20 steps

Ran program for 80 shifts.

Result:

i) At one point (at block (1,3,3)), BWE was digging for a lengthy period of time, but no material on the conveyor belts. However, the bin part of the display indicated material flow into and out of the bin.

ii) Hit a PM that lasted a very long time. Noted that while documentation says ITIMPM and INTPM are to be entered in minutes; the echo in PRINT.DAT says values are hours. The time in this simulation spent in PM would indicate hours is the correct unit.

iii) Ran into almost continuous output conversion errors from line 117 of BWEST.FOR. Problem is format of SIMTIM into FOR021.DAT. Cancelled job after 37 shifts without ever running into an end of section flag.

Volume in Section 1 = 9 x 54,000	=	486,000 bcm
Volume delivered across Conveyor 3	=	474,744 bcm
Operating hrs @ 2700 bcm/hr for Section 1	=	180 hrs
Clock hours @ 75% availability	=	240 hrs
# Hours in 37 shifts	=	296 hrs

Experiment 44:

a) Restored the 10-column version of SEQ.DAT used in Experiment 42(a). Edited DDBASE.DAT to make each block 25 m long. Changed bin outflow to 3000 lcm/hr. Ran program for 30 shifts.

Results: never reached the end of section.

1 step = 25 x 45 x 6 = 6750 bcm = 2.5 hours

Bench #	Section #	# Steps	Volume	Hours	
1	1	44	297000	110.0	(18 shifts)
1	2	45	303750	112.5	
2	1	15	101250	37.5	
2	2	13	87750	32.5	
			789750	292.5	= 49 shifts

Operating hours of BWE	=	169.41
Volume moved by BWE	=	311,611 bcm

So we have a discrepancy in this case too.

Experiment 45:

a) Tried to force Test Case 2 to at least an end of section if not onto another bench. Deleted all reference to the second bench from DDBASE.DAT and SEQ.DAT. Changed bin outflow to 1000 lcm. Block length remained at 25 m. Ran program for 30 shifts.
Result: The following lists all BWE movements as recorded from the terminal (reading down each column):

```
Start
1,2,3  1,3,3  1,3,5  1,3,6  1,3,7  1,3,9  1,3,8  1,3,2
1,3,2  1,3,7  1,3,4  1,3,9  1,3,3  1,3,4  1,3,5  1,3,4
1,3,3  1,3,3  1,3,3  1,3,4  1,3,2  1,3,7  1,3,3  1,3,5
1,3,2  1,3,6  1,3,4  1,3,8  1,3,3  1,3,2  1,3,2  1,3,9
1,3,6  1,3,3  1,3,7  1,3,4  1,3,4  1,3,5  1,3,5  1,3,4
1,3,3  1,3,5  1,3,10 1,3,7  1,3,8  1,3,9  1,3,4  1,3,7
1,3,7  1,3,7  1,3,5  1,3,4  1,3,3  1,3,5  1,3,8  1,3,3
1,3,10 1,3,5  1,3,9  1,3,2  1,3,6  1,3,8  1,3,3  1,3,7
1,3,5  1,3,3  1,3,4  1,3,6  1,3,10 1,3,5  1,3,6  1,3,4
1,3,9  1,3,2  1,3,7  1,3,4  1,3,5  1,3,3  1,3,10 1,3,7
1,3,5  1,3,6  1,3,3  1,3,3  1,3,8  1,3,2  1,3,5  1,3,5
1,3,8  1,3,8  1,3,7  1,3,7  1,3,4  1,3,3  1,3,8  1,3,4
1,3,4  1,3,2  1,3,4  1,3,10 1,3,8  1,3,4  1,3,4  1,3,3
1,3,7  1,3,6  1,3,7  1,3,3  1,3,5  1,3,8  1,3,8  1,3,6
1,3,5  1,3,9  1,3,5  1,3,6  1,3,7  1,3,9  1,3,5  1,3,10
1,3,4  1,3,4  1,3,6  1,3,10 1,3,3  1,3,3  1,3,3  1,3,8
1,3,3  1,3,8  1,3,5  1,3,5  1,3,6  1,3,7  1,3,6  1,3,3
1,3,6  1,3,3  1,3,2  1,3,8  1,3,5  1,3,10 1,3,5  1,3,7
1,3,10 1,3,7  1,3,4  1,3,4  1,3,2  1,3,5  1,3,2  1,3,3
1,3,5  1,3,4  1,3,7  1,3,8  1,3,4  1,3,9  1,3,4  1,3,6
1,3,8  1,3,7  1,3,2  1,3,5  1,3,5  1,3,5  1,3,7  1,3,3
                                                 1,3,7
                                                   End
```

Similar patterns were shown in all Test Case 3 experiments. Note the apparently random jumping between columns and the way that the BWE appears "stuck" on layer 3. There is apparently an index problem.

We compared the data files of Test Case 1 (Experiment 46) with Test Case 3 (Experiment 45). Note that in Experiment 46 the simulator successfully moved between sections.

File	Item	Test Case 1	Test Case 3
BCB.EXE	No difference		
CNSTAT.DAT	No difference		
INPOUT.DAT	No difference		
GASP.DAT	No difference		
DIST.DAT	Max. time between mech. breakdown	3840	7680
ATRIB.DAT	Conveyor move time	8	87
	Hinge distance	18	24
BIN.DAT	Bin outflow	2250	2500
	Bin coordinates	Different	
CONVEY.DAT	Max. belt capacity	14071	4071
	Capacity factor	68	99
	Conveyor lengths	Different	
	Conveyor head, tail and load point coordinates	Different	
DDBASE.DAT	Block length	200	25
	Boulder probability	0.01	0.05
	Number of layers	4	5
	Coordinates	Different	
SEQ.DAT	Number of steps	31	89
	Order of mining	Different	

The hinge height or number of layers are the most probable cause of difficulty with this part of Test Case 3.

Experiment 47:

a) Returned block length to 200 m, bin outflow to 2250, hinge distance to 18.0 m and lowered layer height to 4.5 m. The experiment was to see if the 24 m hinge height made it impossible to reach the lower layers. Ran program for 63 shifts (21 days) with screen updates once daily.
Result:

Day	BWE Position
1	1,3,2
2	1,3,5
3	1,3,3
4	1,3,6
5	1,3,7
6	1,3,5
7	1,3,3
8	1,3,3
9	1,3,6
10	1,3,8

Cancelled job when program ran into almost continuous output conversion errors at line 117 of BWEST.

Table C-1

BIN.DAT

```
1,7,
1,
1,2,3,4,5,6,7,
5,99999,5000,100,99,8080,1605,1,1,
1,3,7,30,9,0,0,0,0,0,
4,
11,1,1,1,2,                              / DURATION OF BLOCKAGE
12,600000,1000,590000,900000,            / TIME BETWEEN BLOCKAGES
13,1,1,1,2,                              / DURATION OF BREAKDOWN
14,600000,1000,590000,900000,            / TIME BETWEEN BREAKDOWNS
```

Table C-2

CNSTAT.DAT

```
2,3,16,
1,1,2,2,2,2,2,2,
2,3,3,3,3,4,4,4,
6,
480.,480.,240.,2800.,     / TIME BETWEEN MECH B'DOWNS  (4F10.2)
30.,30.,15.,4320.,        / TIME TO REPAIR MECH BREAKDOWN
1920.,1920.,960.,11520.,   / TIME BETWEEN ELEC BREAKDOWNS
120.,120.,60.,1920.,      / TIME TO REPAIR ELEC BREAKDOWN
960.,960.,60.,2880.,      / TIME BETWEEN CONVEYOR TRIPS
5.0,1.5,2.0,15.,            / TIME TO RESET AFTER TRIP
```

Table C-3

CONVEY.DAT

```
30.,35.,
240.,15.24,0.8,15.,
5.0,0.91,0.2,0.8,
3,1.0,480.,
4071  70.86  35.5   9560   800  736   6450   785  745  1 100  W
4071  70.86  35.5   9580  1605  764   9550   530  736  1 100  N
4071  70.86  35.5   8080  1605  782   9580  1605  764  1 100  E
1,0,0,0,0,0,1,1,3,2,0,2900,0,0,6660,785,
1,0,0,0,0,0,3,1,3,3,0,805,0,0,9560,800,
1,0,3,2,0,0,0,0,4,1,0,0,0,0,0,0,
1,
1,3,3,3,4,
1,1,2,3,1,
```

Table C-4

ATRIB.DAT

```
0,8,0.08,1.0,              / CUTCRD, CONVMT, REVSLT, SEAFAC
15,225,1,0,387,            / ITIMPM, INTPM, ISEAFL, BLSTRE, COSTOP
12.0,8,1.1,1,3600,         / RESMAX, HROFST, WCAKFC, IHISFL, TUPM
3,1,0,1,5.5,0,            / CLENTM, NCOMB, IATTEN, JPAUSE, SLOTIM, IDISFL
1900,                          / BWE ID #
2,1,1,                       / STATUS, DEVICE FOR ORE, DEVICE FOR WASTE
1,14,6.5,                   / FEEDER FLAG, # BUCKETS, WHEEL RADIUS
43.0,1.7,18.0,               / BOOM LENGTH, BUCKET WIDTH, HINGE DIST
1.9,10.0,0.9,                / BUCKET CAPACITY, CRAWLER SPEED, OPERATOR EFF.
160.0,2.0,0,                 / BELT LENGTH, BELT WIDTH, # PRECUTTERS
1.7,0,0,                     / BUCKET LENGTH, KNIFE FLAG, # TEETH
1920000,22.0,0.05,           / STRUCTURE WEIGHT, BALL RACE DIAM, COEFF FRICT.
9.0,14.5,2,                  / HOR DIST, FORWARD DIST, BELTWAGON FLAG
135.0,4.0,0.80,              / BELT WT, BELT SPEED, MOTOR EFF.
0.03,0.17,2,                 / BELT COEFF FRICT, ROLLING RESIST, TOTAL RESIST
1,                             / OUTPUT DEVICE NUMBER
```

Table C-5

DIST.DAT

```
       1.0       .01      0.99      1.01 / BOULDER DELAYS
       1.0       .01      0.99      1.01 / WASTE-FEED CHANGEOVER TIME
     240.0     240.0      30.0     480.0 / TIME TO REPAIR TOOTH
    6000.0     100.0    5000.0    7000.0 / TIME BETWEEN TOOTH DELAYS
  1900
       1.0       0.6       0.5       1.5 / SLICE TIME
     240.0     240.0      30.0     960.0 / TIME TO REPAIR MECH BREAKDOWN
     960.0     960.0     240.0    7680.0 / TIME BETWEEN MECH BREAKDOWN
    1440.0    1440.0     480.0    4320.0 / TIME TO REPAIR ELECT BREAKDOWN
    5660.0    5660.0     960.0   17280.0 / TIME BETWEEN ELECT BREAKDOWN
9999999999999999999999999999999999999999
```

Table C-6

DDBASE.DAT

```
1
      45.00        200.00         6.00     6660.00       785.00       744.00
    9460.00        800.00       736.00     6655.00       605.00       745.00
    9455.00        620.00       736.00        4.00         5.00        14.00
      60.00          0.00         0.00
1  1  1   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  1   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  1   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  1   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  1   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  2   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  2   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  2   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  2   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  2   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  3   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  3   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  3   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  3   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  3   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  4   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  4   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  4   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  4   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  4   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  5   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  5   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  5   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  5   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  5   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  6   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  6   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  6   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  6   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  6   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  7   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  7   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  7   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  7   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  7   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  8   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  8   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  8   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  8   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  8   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1  9   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2  9   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3  9   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4  9   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5  9   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1 10   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2 10   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3 10   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4 10   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5 10   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  1 11   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  2 11   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  3 11   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  4 11   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
1  5 11   0.00   0.002200.00   7.00   9.00 40.00   0.05   2.00   3.00
```

Table C-6 (cont'd)

1	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	1	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	2	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	3	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	4	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
1	5	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00

Table C-6 (cont'd)

2	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	1	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	2	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	3	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	4	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
2	5	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	6	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	7	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00

Table C-6 (cont'd)

3	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	8	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	9	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	10	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	11	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	12	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	13	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	1	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	2	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	3	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	4	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
3	5	14	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	3	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	4	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	5	1	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	3	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	4	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	5	2	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	3	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	4	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	5	3	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	3	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	4	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	5	4	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	3	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	4	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00
4	5	5	0.00	0.002200.00	7.00	9.00	40.00	0.05	2.00	3.00

Table C-6 (cont'd)

```
4  1  6  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2  6  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3  6  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4  6  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5  6  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1  7  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2  7  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3  7  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4  7  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5  7  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1  8  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2  8  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3  8  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4  8  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5  8  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1  9  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2  9  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3  9  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4  9  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5  9  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1 10  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2 10  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3 10  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4 10  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5 10  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1 11  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2 11  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3 11  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4 11  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5 11  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1 12  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2 12  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3 12  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4 12  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5 12  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1 13  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2 13  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3 13  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4 13  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5 13  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  1 14  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  2 14  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  3 14  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  4 14  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
4  5 14  0.00  0.002200.00  7.00  9.00 40.00   0.05  2.00  3.00
2
       45.00  200.00       6.00    6660.00      785.00     744.00
     9460.00  800.00     736.00    6655.00      605.00     745.00
     9455.00  620.00     736.00       4.00        2.00      14.00
       60.00    0.00       0.00
1  1  1  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  2  1  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  1  2  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  2  2  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  1  3  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  2  3  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  1  4  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  2  4  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  1  5  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
1  2  5  0.00  0.002200.00  7.00  9.00 40.00   0.01  2.00  3.00
```

Table C-6 (cont'd)

1	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	1	14	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
1	2	14	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	8	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	9	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	10	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	11	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	12	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	13	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	1	14	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
2	2	14	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	1	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	2	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	3	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	4	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	5	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	6	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	1	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00
3	2	7	0.00	0.002200.00	7.00	9.00	40.00	0.01	2.00	3.00

Table C-6 (cont'd)

```
   3  1  8   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2  8   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1  9   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2  9   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1 10   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2 10   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1 11   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2 11   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1 12   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2 12   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1 13   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2 13   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  1 14   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   3  2 14   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  1   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  1   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  2   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  2   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  3   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  3   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  4   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  4   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  5   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  5   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  6   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  6   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  7   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  7   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  8   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  8   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1  9   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2  9   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1 10   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2 10   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1 11   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2 11   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1 12   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2 12   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1 13   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2 13   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  1 14   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
   4  2 14   0.00   0.002200.00  7.00  9.00 40.00  0.01  2.00  3.00
99999
```

Table C-7

PITCHG.DAT

```
1   1
1   2
```

Table C-8

SEQ.DAT

```
1900
1  5  1
1  3  2
1  4  2
1  5  2
1  1  3
1  2  3
1  3  3
1  4  3
1  5  3
1  1  4
1  2  4
1  3  4
1  4  4
1  5  4
1  1  5
1  2  5
1  3  5
1  4  5
1  5  5
1  1  6
1  2  6
1  3  6
1  4  6
1  5  6
1  1  7
1  2  7
1  3  7
1  4  7
1  5  7
1  1  8
1  2  8
1  3  8
1  4  8
1  5  8
1  1  9
1  2  9
1  3  9
1  4  9
1  5  9
1  1 10
1  2 10
1  3 10
1  4 10
1  5 10
1  1 11
1  2 11
1  3 11
1  4 11
1  5 11
1  1 12
1  2 12
1  3 12
1  4 12
1  5 12
1  1 13
1  2 13
1  3 13
1  4 13
1  5 13
```

Table C-8 (cont'd)

1	1	14
1	2	14
1	3	14
1	4	14
1	5	14
2	1	14
2	2	14
2	3	14
2	4	14
2	5	14
2	1	13
2	2	13
2	3	13
2	4	13
2	5	13
2	1	12
2	2	12
2	3	12
2	4	12
2	5	12
2	1	11
2	2	11
2	3	11
2	4	11
2	5	11
2	1	10
2	2	10
2	3	10
2	4	10
2	5	10
2	1	9
2	2	9
2	3	9
2	4	9
2	5	9
2	1	8
2	2	8
2	3	8
2	4	8
2	5	8
2	1	7
2	2	7
2	3	7
2	4	7
2	5	7
2	1	6
2	2	6
2	3	6
2	4	6
2	5	6
2	1	5
2	2	5
2	3	5
2	4	5
2	5	5
2	1	4
2	2	4
2	3	4
2	4	4
2	5	4

Table C-8 (cont'd)

2	1	3
2	2	3
2	3	3
2	4	3
2	5	3
2	2	2
2	3	2
2	4	2
2	5	2
2	5	1
3	4	2
3	5	2
3	1	3
3	2	3
3	3	3
3	4	3
3	5	3
3	1	4
3	2	4
3	3	4
3	4	4
3	5	4
3	1	5
3	2	5
3	3	5
3	4	5
3	5	5
3	1	6
3	2	6
3	3	6
3	4	6
3	5	6
3	1	7
3	2	7
3	3	7
3	4	7
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3	2	8
3	3	8
3	4	8
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3	1	9
3	2	9
3	3	9
3	4	9
3	5	9
3	1	10
3	2	10
3	3	10
3	4	10
3	5	10
3	1	11
3	2	11
3	3	11
3	4	11
3	5	11
3	1	12
3	2	12
3	3	12

Table C-8 (cont'd)

3	4	12
3	5	12
3	1	13
3	2	13
3	3	13
3	4	13
3	5	13
3	1	14
3	2	14
3	3	14
3	4	14
3	5	14
4	1	14
4	2	14
4	3	14
4	4	14
4	5	14
4	1	13
4	2	13
4	3	13
4	4	13
4	5	13
4	1	12
4	2	12
4	3	12
4	4	12
4	5	12
4	1	11
4	2	11
4	3	11
4	4	11
4	5	11
4	1	10
4	2	10
4	3	10
4	4	10
4	5	10
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4	2	9
4	3	9
4	4	9
4	5	9
4	1	8
4	2	8
4	3	8
4	4	8
4	5	8
4	1	7
4	2	7
4	3	7
4	4	7
4	5	7
4	1	6
4	2	6
4	3	6
4	4	6
4	5	6
4	1	5
4	2	5
4	3	5

Table C-8 (cont'd)

```
  4  4  5
  4  5  5
  4  1  4
  4  2  4
  4  3  4
  4  4  4
  4  5  4
  4  1  3
  4  2  3
  4  3  3
  4  4  3
  4  5  3
  4  4  2
  4  5  2
  4  5  1
999999999
  1900
  1  2  3
  1  1  4
  1  2  4
  1  1  5
  1  2  5
  1  1  6
  1  2  6
  1  1  7
  1  2  7
  1  1  8
  1  2  8
  1  1  9
  1  2  9
  1  1 10
  1  2 10
  1  1 11
  1  2 11
  1  1 12
  1  2 12
  1  1 13
  1  2 13
  1  1 14
  1  2 14
  2  1 14
  2  2 14
  2  1 13
  2  2 13
  2  1 12
  2  2 12
  2  1 11
  2  2 11
  2  1 10
  2  2 10
  2  1  9
  2  2  9
  2  1  8
  2  2  8
  2  1  7
  2  2  7
  2  1  6
  2  2  6
  2  1  5
  2  2  5
```

Table C-8 (cont'd)

```
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APPENDIX D

REFERENCE TABLES FROM DOCUMENTATION

TABLE 1-D

Bin/Hopper Model Events

401	Change inflow rate/grade to a bin.
402	Update the current volume/grade in a bin.
403	Change the outflow rate/grade from a bin.
404	Alert the sources of feed either to start or to stop.
405	Request by feeding equipment to move hopper.
406	Start of hopper move.
407	End of hopper move.
408	Start of bin/hopper blockage/breakdown.
409	End of bin/hopper blockage/breakdown.
410	Start of bin/hopper p.m./minor repair.
411	End of bind/hopper p.m./minor repair.
412	Alert bin/hopper that output device has become non-operational.
413	Alert bin/hopper that output device has become ready.
414	Update hourly statistics and print report.

TABLE 2-D

CONPA.DES - Conveyor Parameters

CONPA(I,J)   I = Conveyor No.

J= 1	Capacity (bcm/hr)	
2	Width (in)	
3	Area (sq. ft.)	
4	Belt weight (lb/ft)	
5	Speed (ft/min)	
6	Length (metre)	
7	X coordinate	Head (metre)
8	Y coordinate	
9	Z coordinate	
10	X coordinate	Tail (metre)
11	Y coordinate	
12	Z coordinate	
13	Pit No.	
14	Capacity % factor	
15	Direction designation	
16	Varying coordinate (1 for X, 2 for Y)	

TABLE 3-D

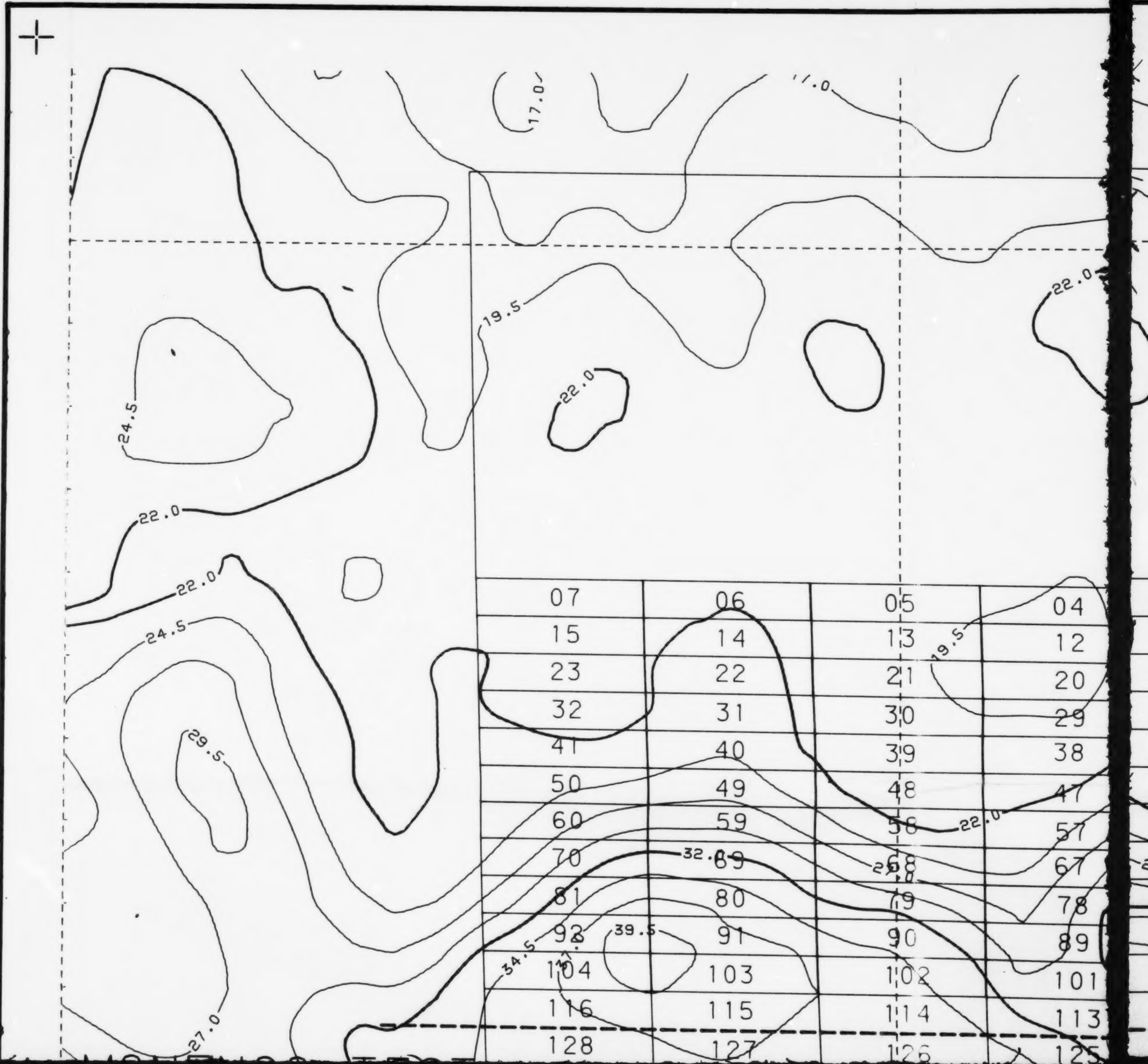
CONSTA.DES - Conveyor Status Assignment

1	Running empty	Operating
2	Running loaded	
3	Waiting	Delays
4	Move	
5	Minor repair	
6	Tripped	
7	Switchover	
8	Reverse	
9	Misc. Delay	
10	Idle	
11	Power Outage	
12	Standby	
13	Not required	
14	Mech. breakdown	
15	Elec. breakdown	
16	Prev. maint.	

TABLE 4-D

Events.DES - Event No. Assignment

301	Change feed rate/grade to a conveyor.
302	Update flow rate/grade at a feeder or output point.
303	Overload trip.
304	Belt protection trip.
305	Restart after tripping or stopping.
306	Return to normal power consuming state.
307	Stop a specific conveyor and all conveyors upstream.
308	Update statistics and print hourly report.
309	Alert operator re conveyor running empty.
310	Request by feeding equipment for conveyor to move.
311	Start of conveyor move.
312	End of conveyor move.
313	Start of prev. maint.
314	End of prev. maint.
315	Start of minor repair.
316	End of minor repair.
317	Start of switchover.
318	End of switchover.
319	Start of reverse.
320	End of reverse.
321	Start of breakdown.
322	End of breakdown.
399	Update alphanumeric display.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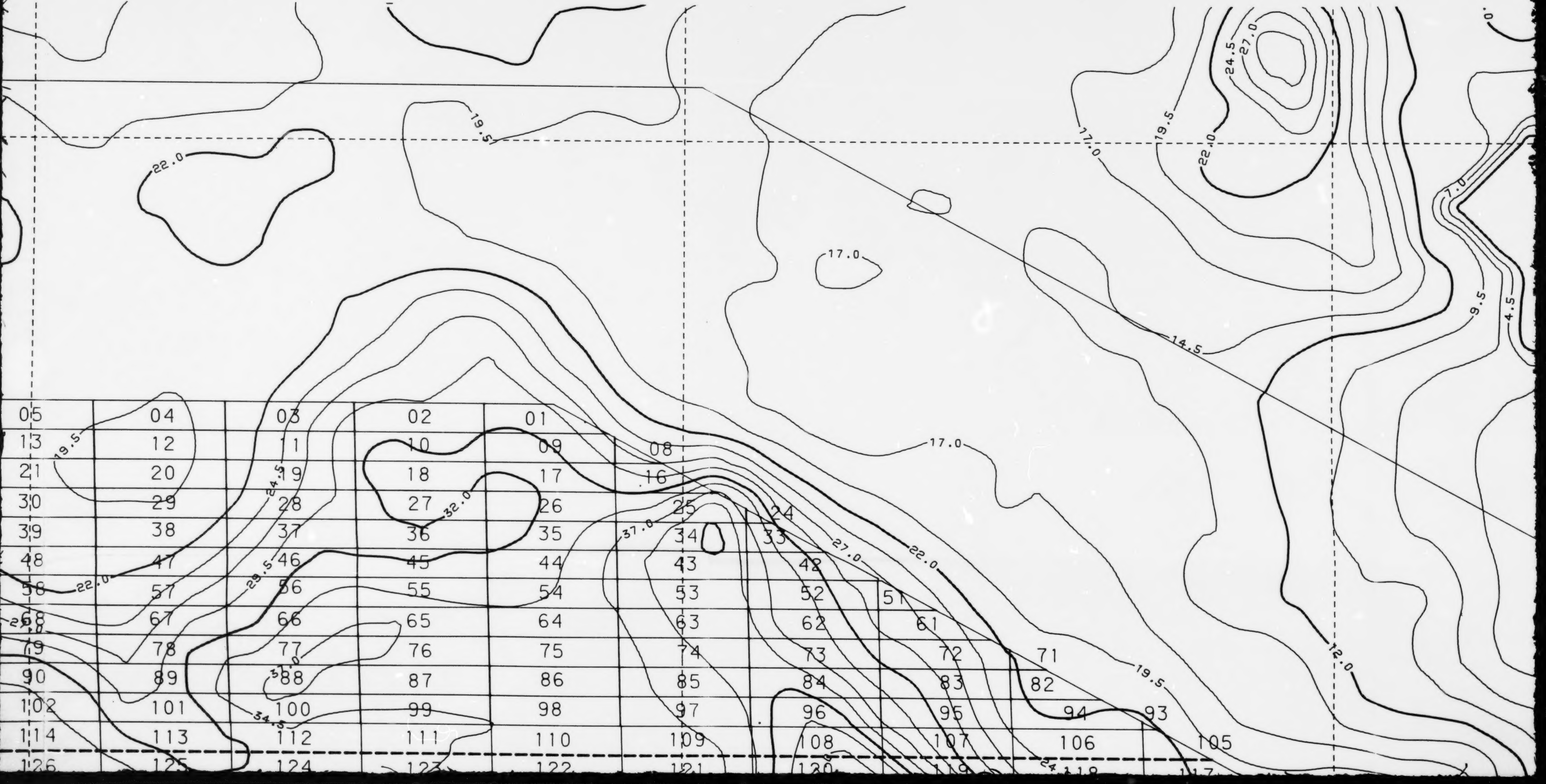
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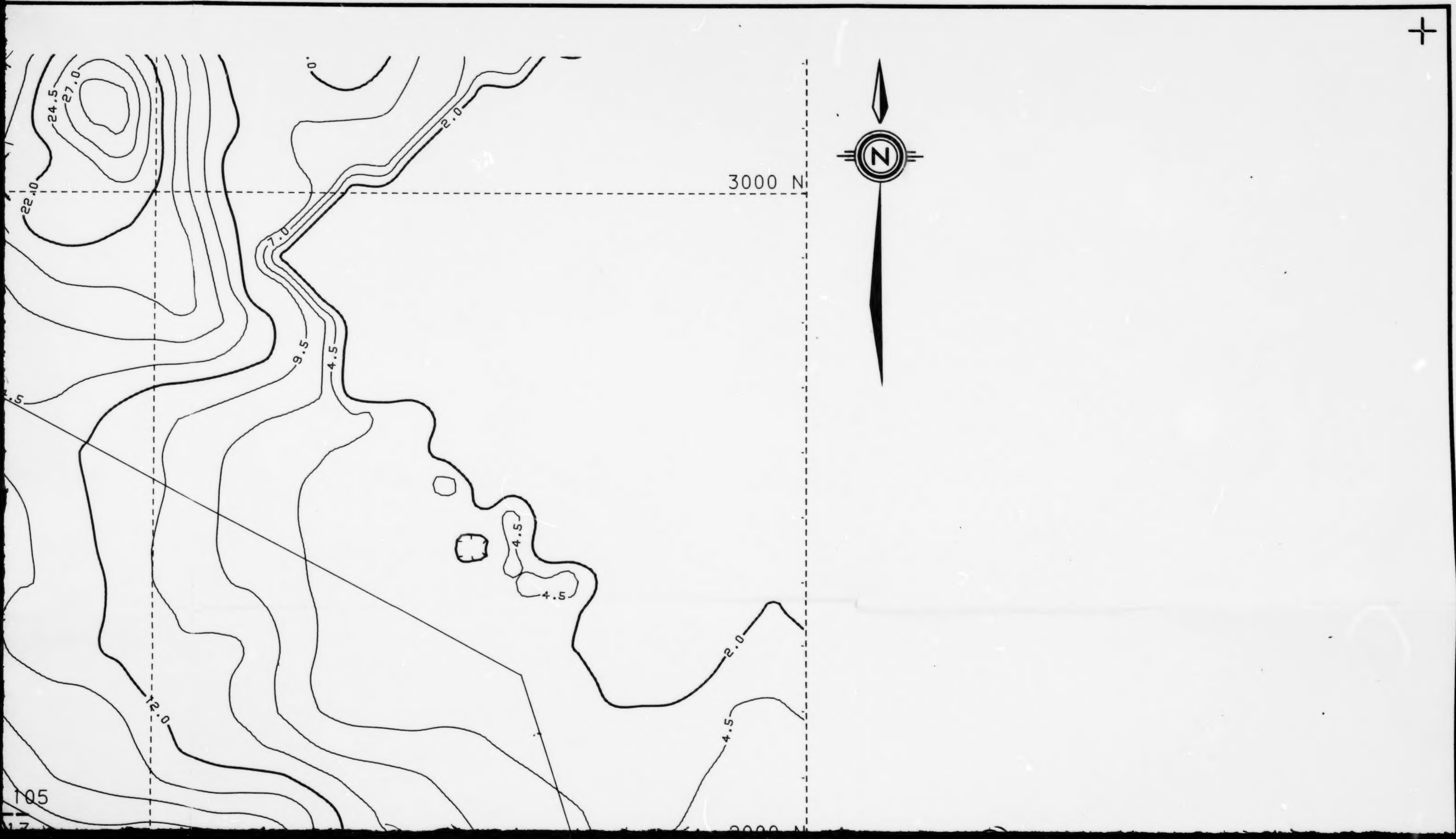
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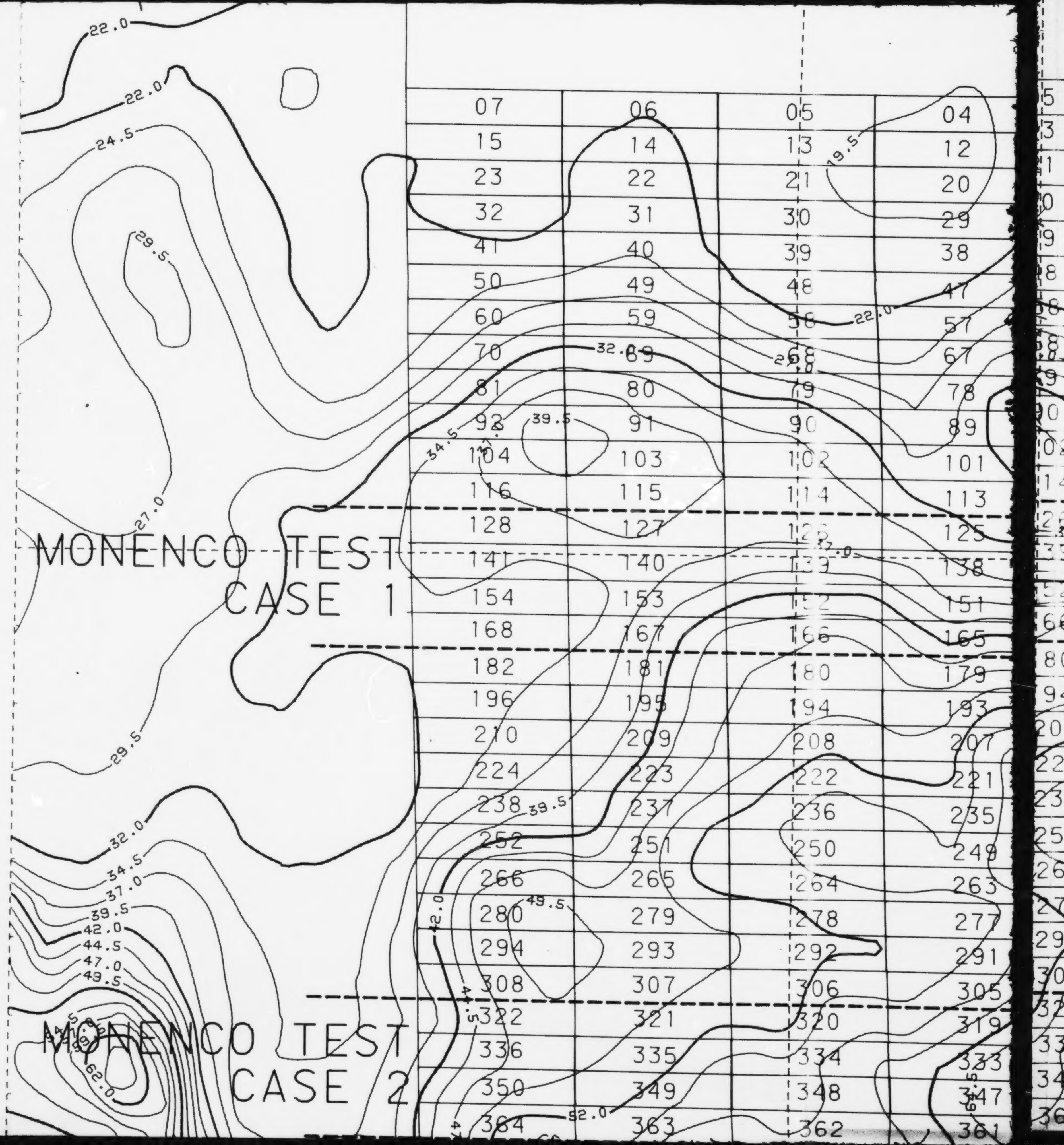
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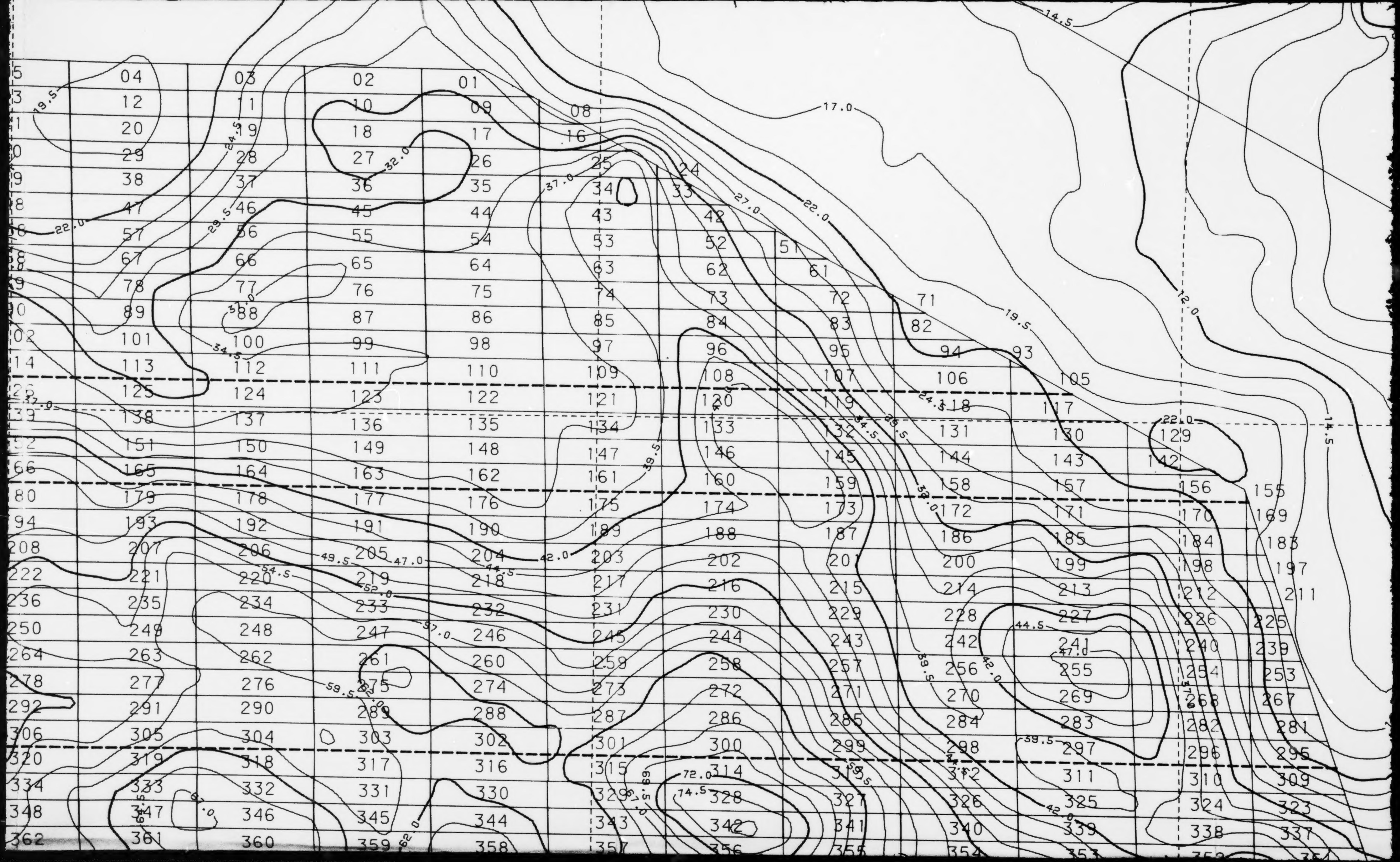
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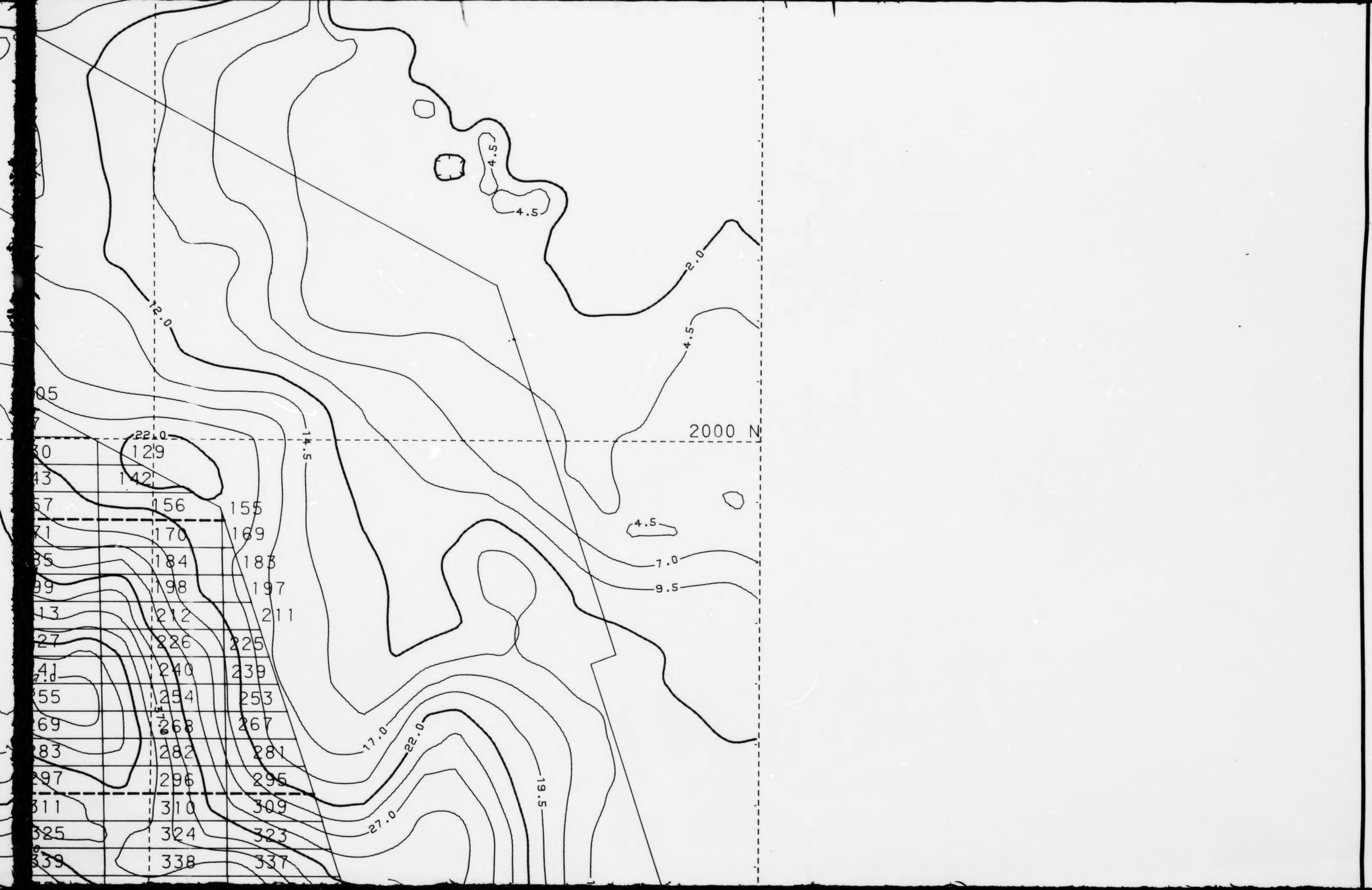
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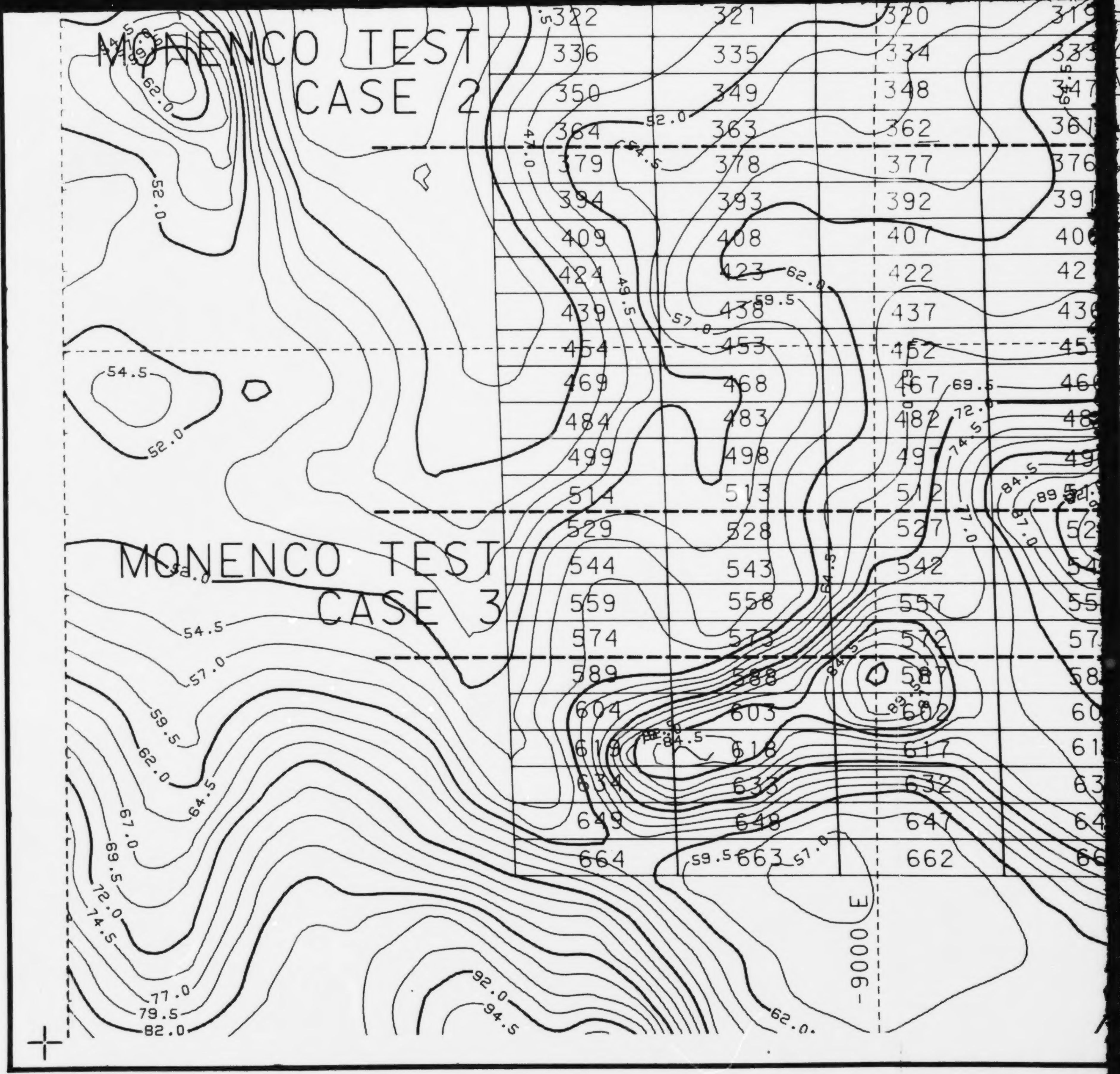
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MONENCO TEST
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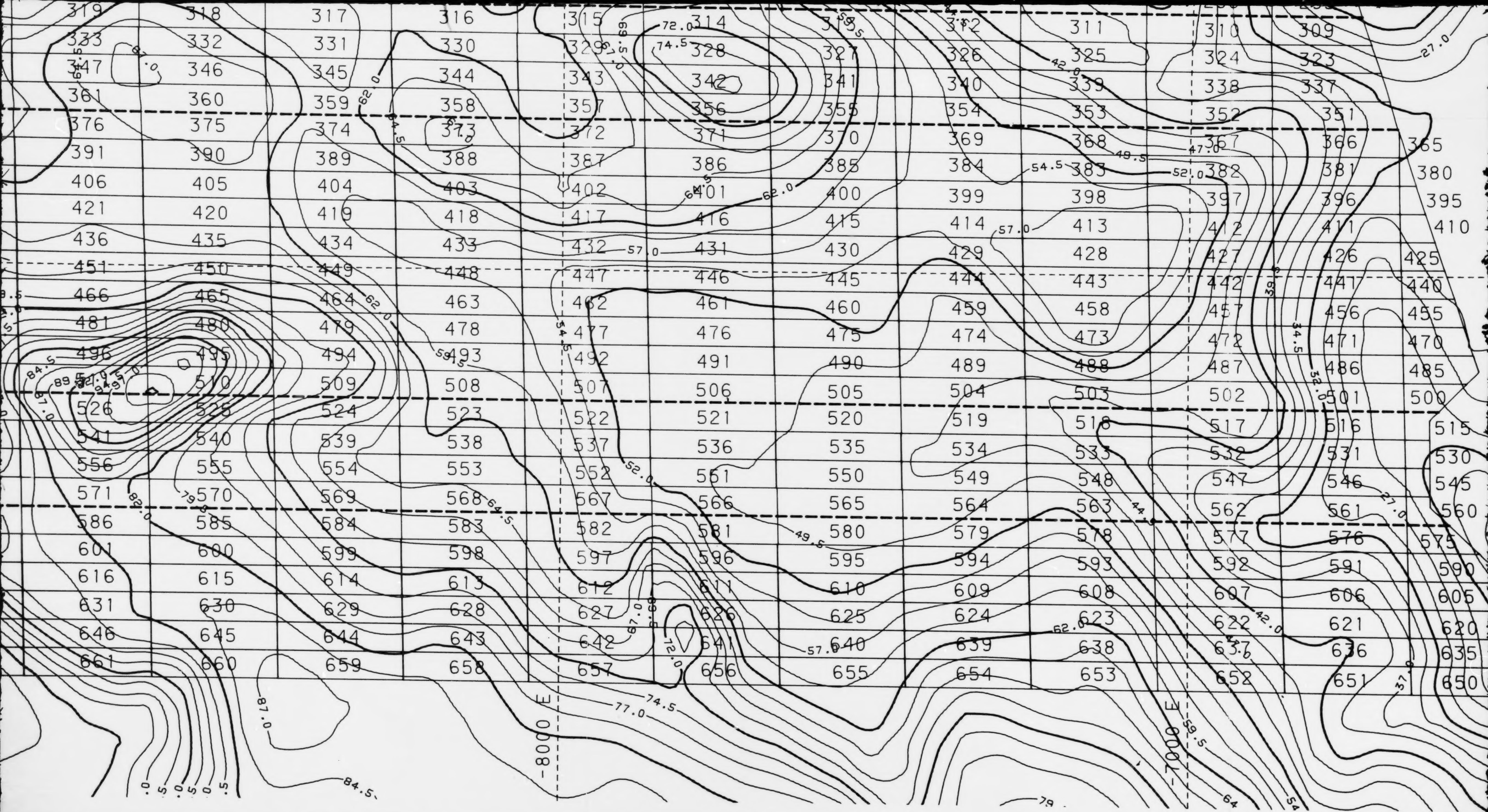
TRANSLAR 290-3-79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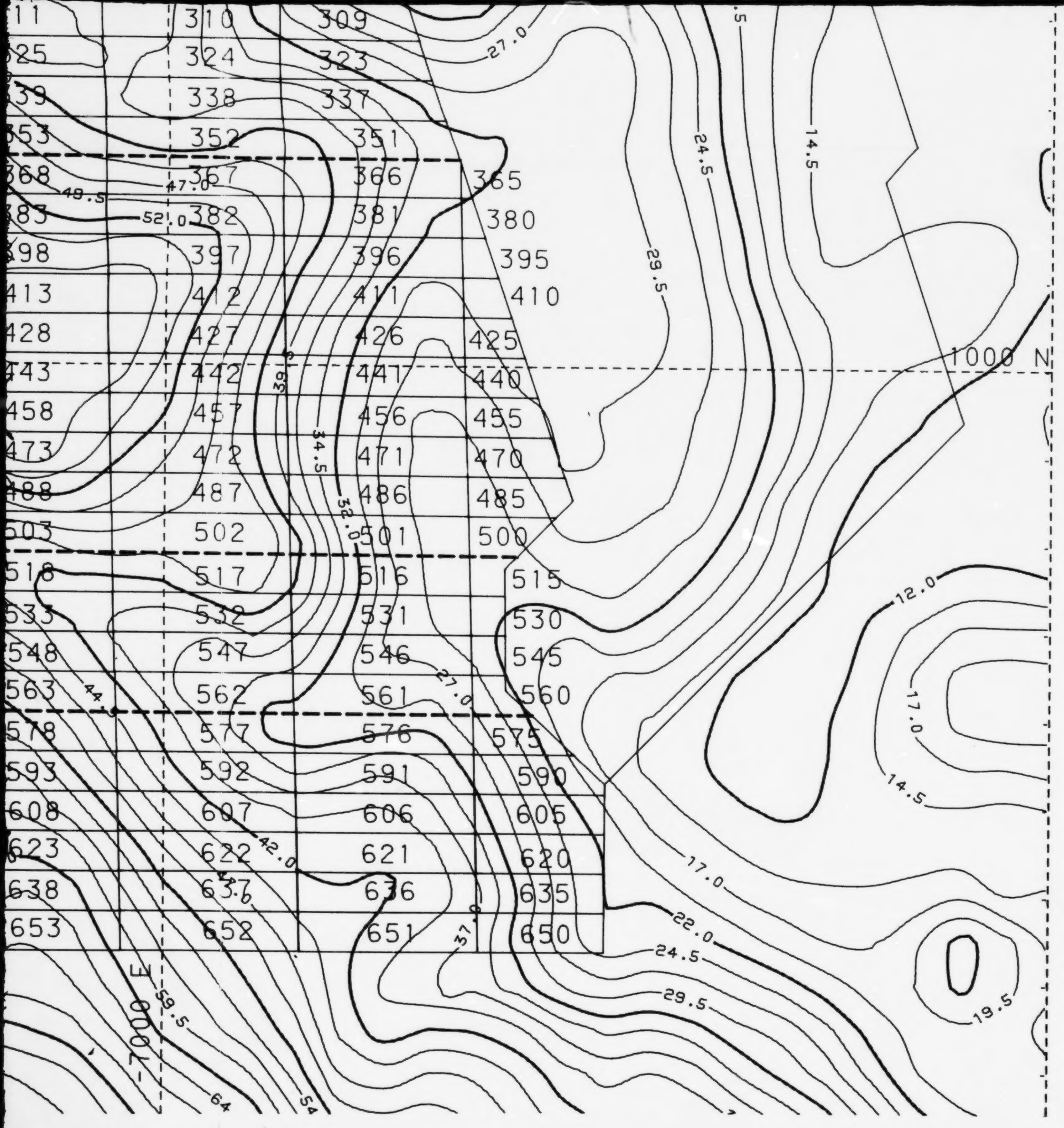
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200
300
400
500 METRES

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

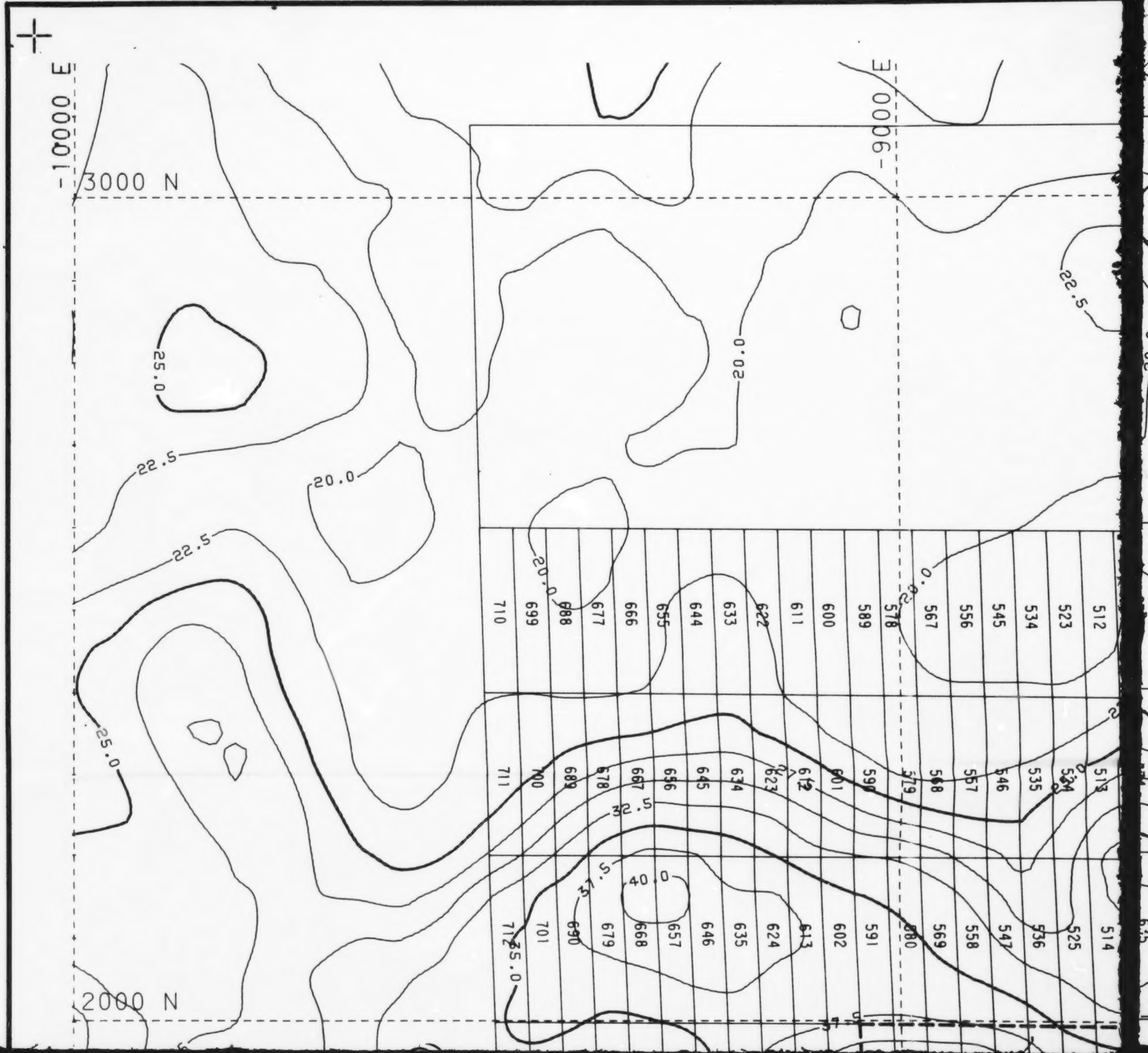
THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

MONENCO TEST CASES

MONENCO LIMITED

1986-08-20 DATE	DSS 8291-8 WORK ORDER 003978 SUBCODE 017 SYSTEM	FIGURE 4-1

2.5Q 60%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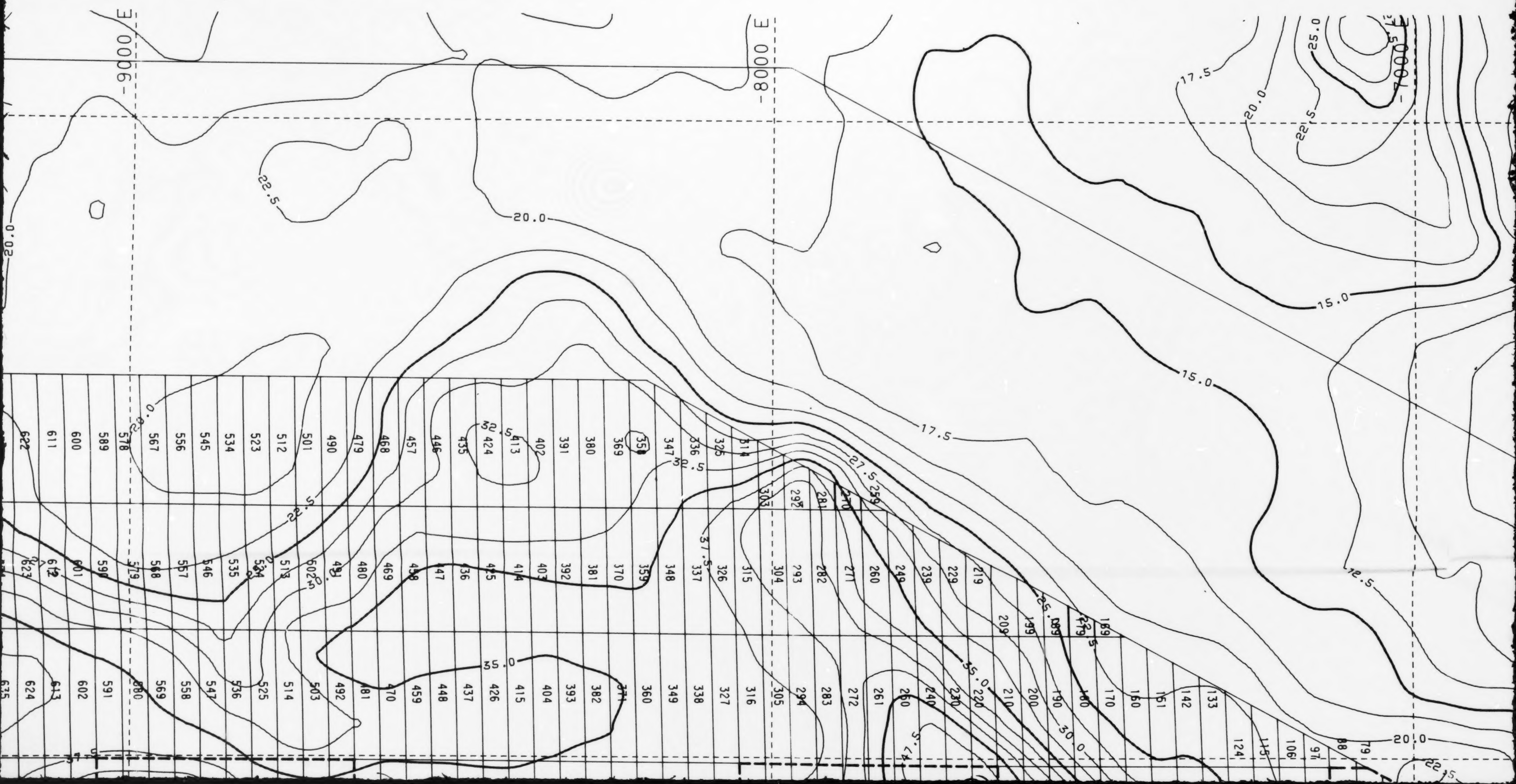

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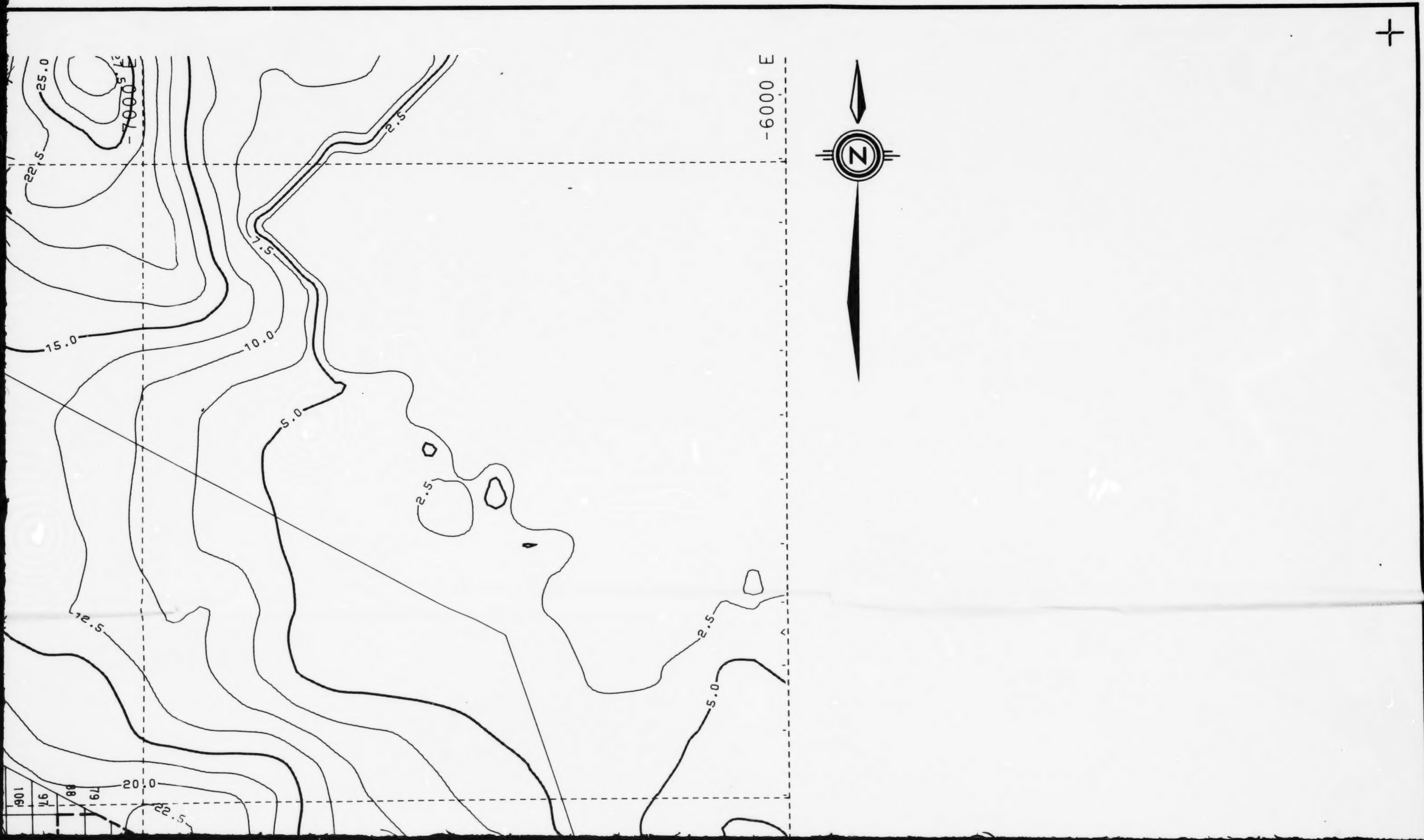
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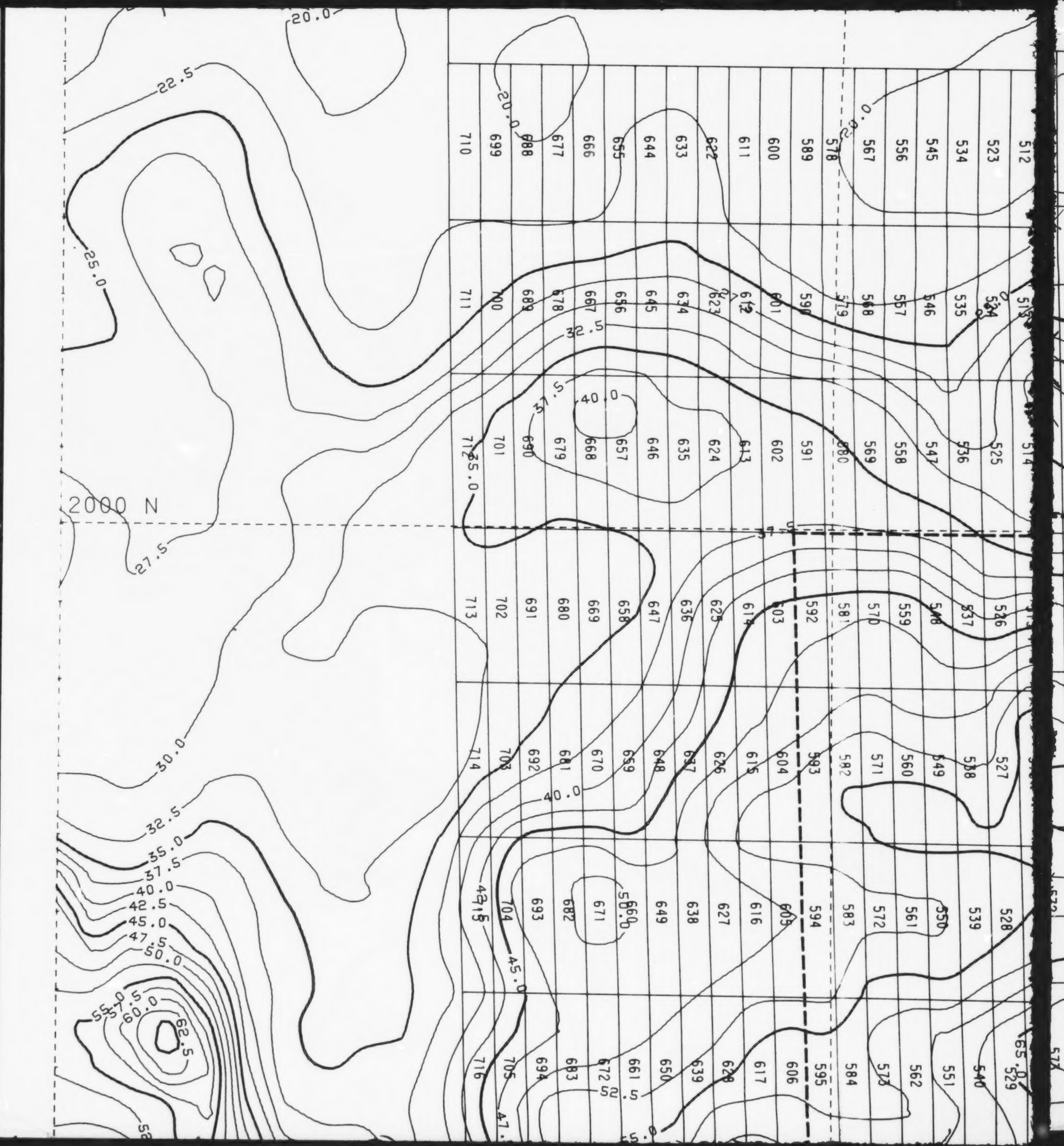
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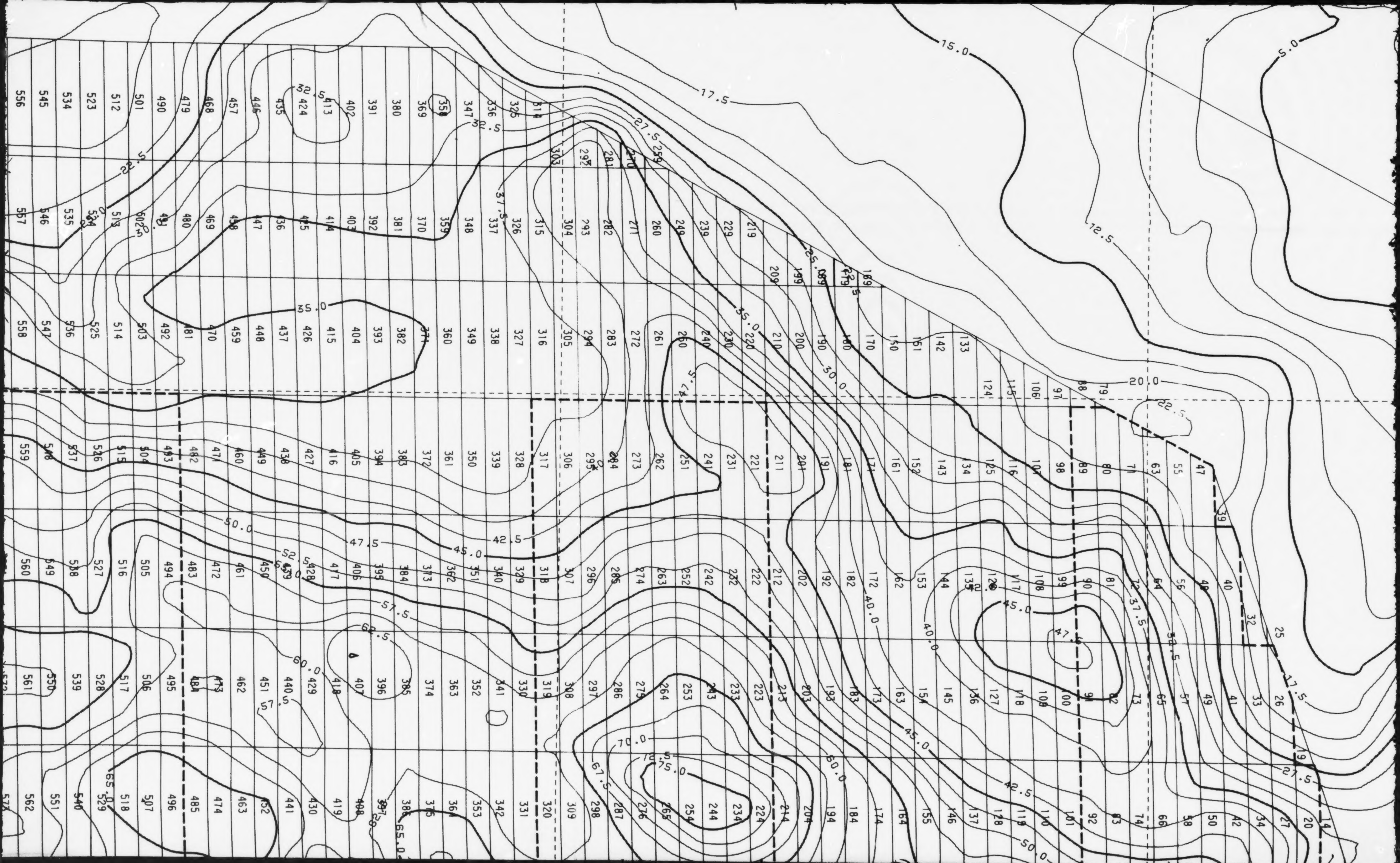
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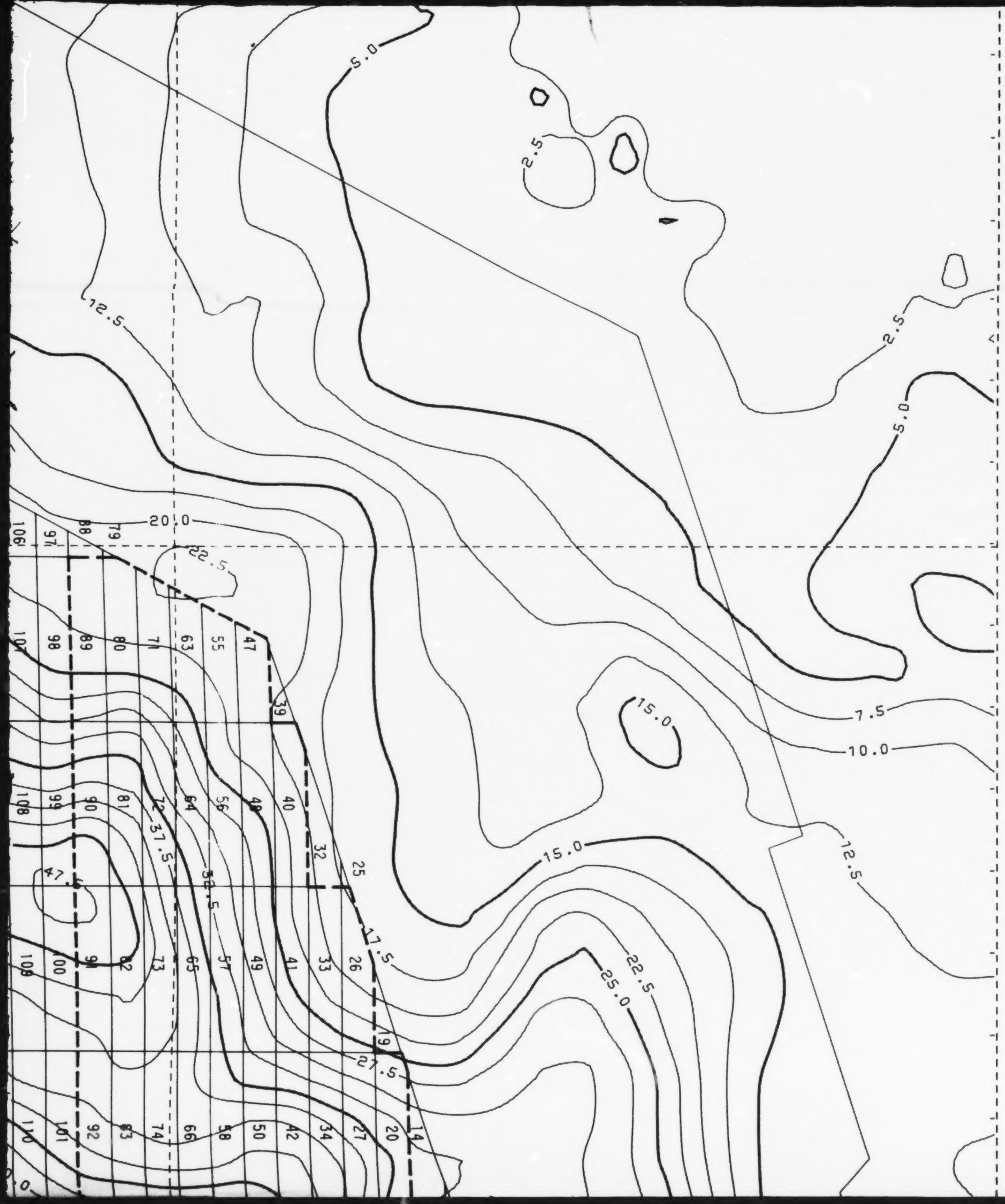
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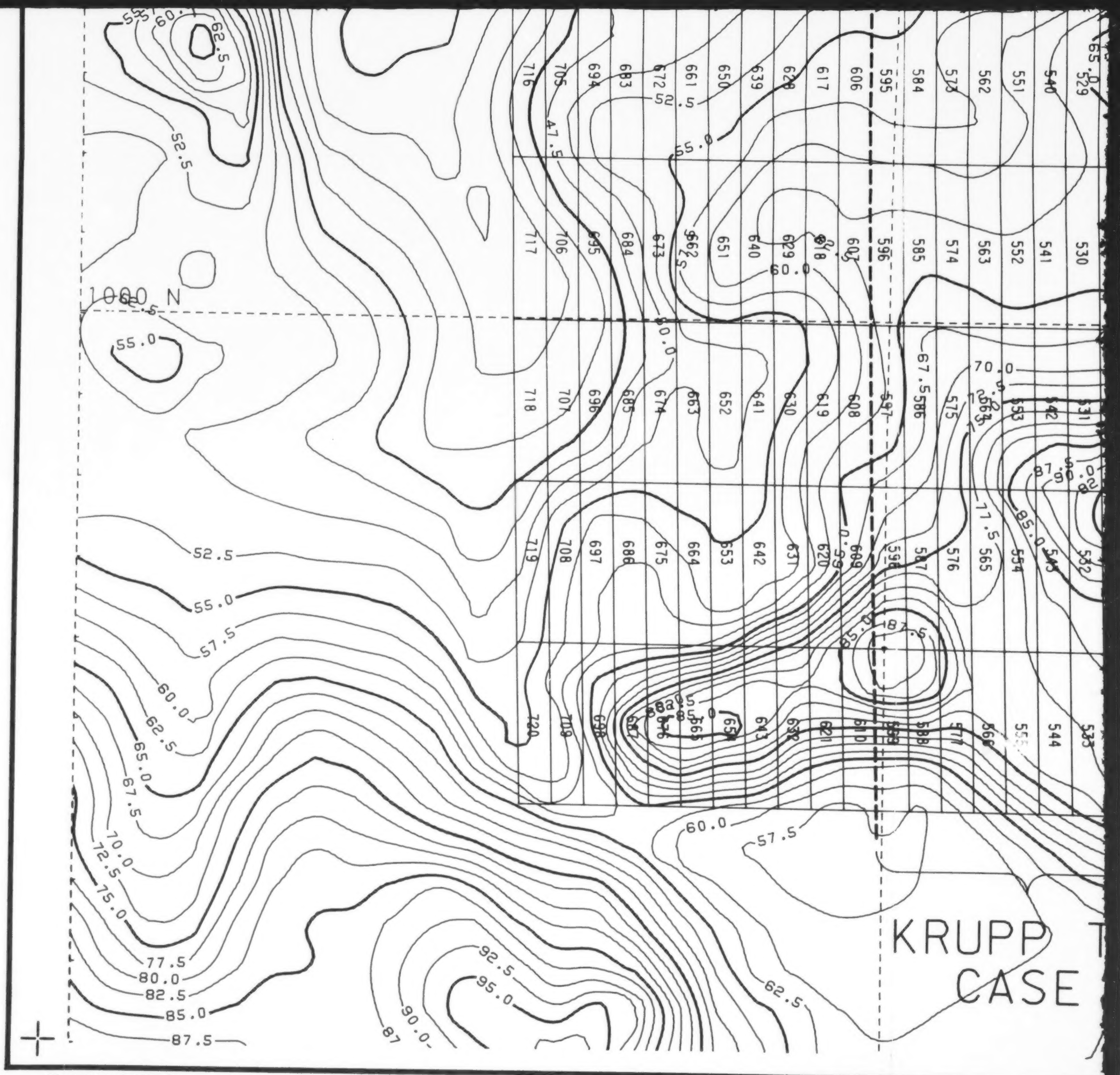
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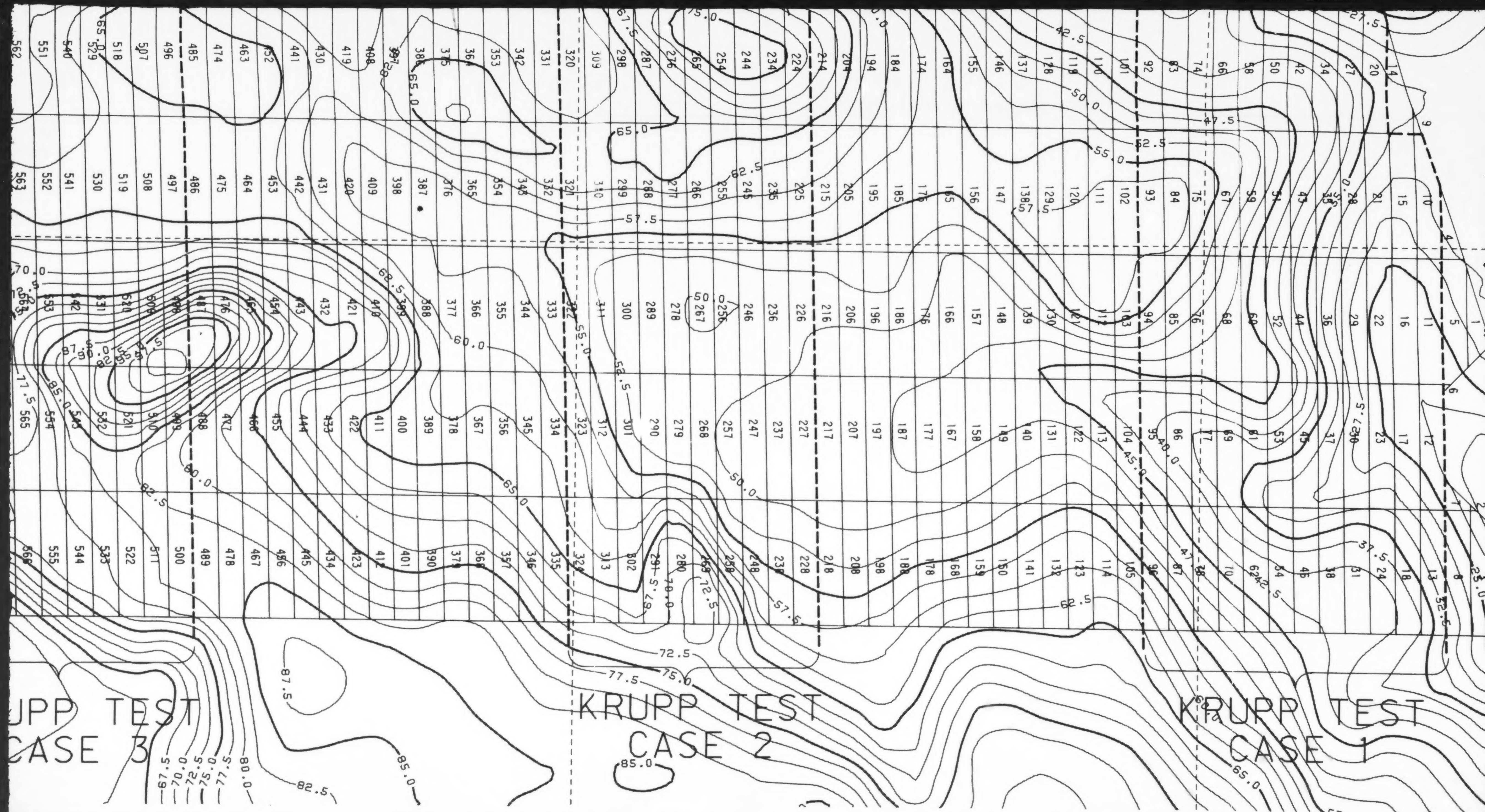
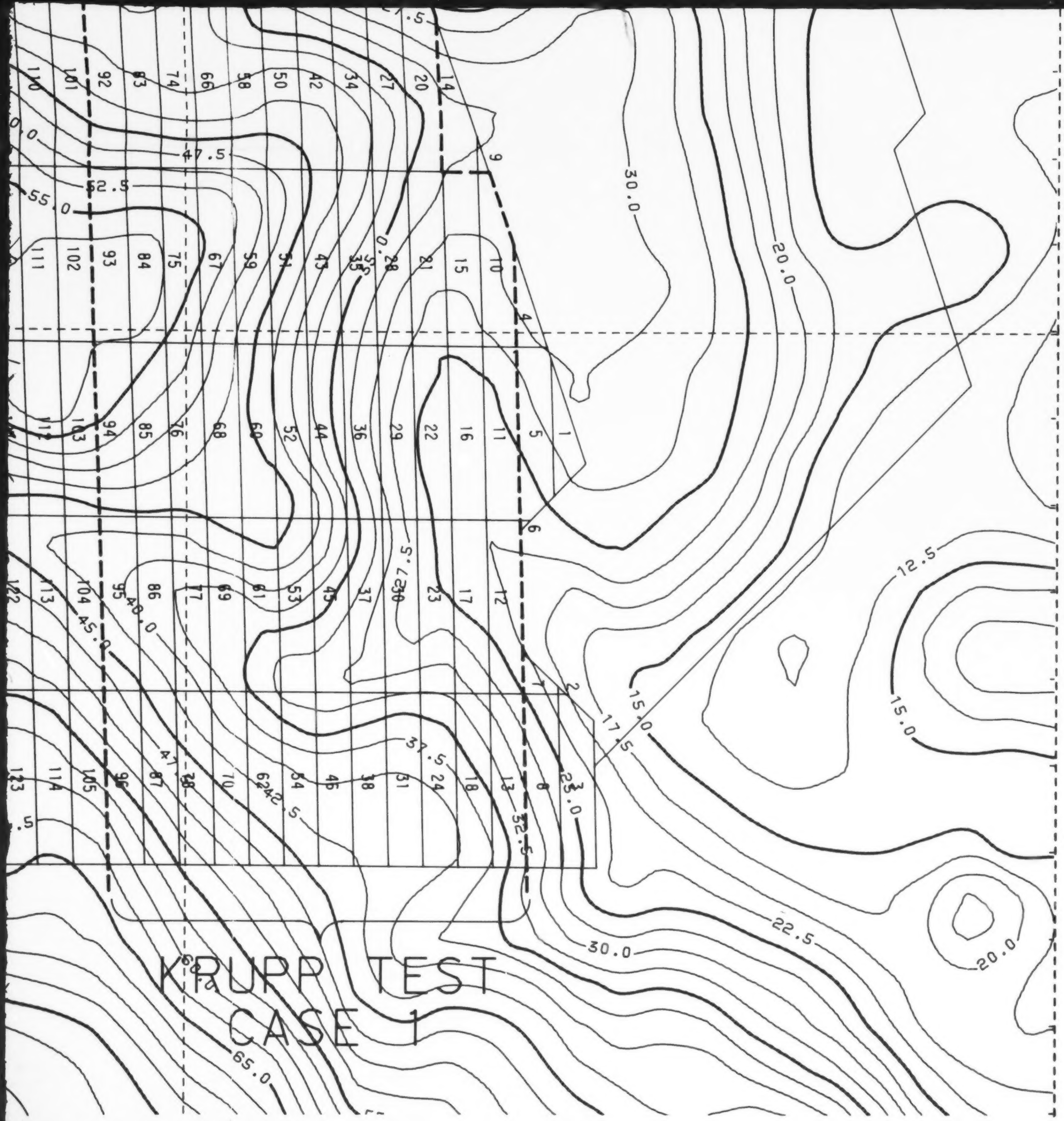
653
642
631
620
609
598
587
576
565
554
543
532
720
709
698
687
676
665
654
643
632
621
610
599
588
577
566
555
544
533

TRANSLAR 250-3-79


UPP TEST
CASE 3
KRUPP TEST
CASE 2
KRUPP TEST
CASE 1
65.0
57.5
62.5
55.0
52.5
50.0
47.5
42.5
60.0
70.0
72.5
75.0
77.5
80.0
82.5
85.0
87.5
90.0


KRUPP TEST
CASE 1
30.0
20.0
12.5
15.0
15.0
17.5
22.5
20.0
30.0
65.0
47.5
52.5
55.0
45.0
40.0
37.5
27.5
32.5
25.0
42.5
0 100 200 300 400 500 METRES

REVISION	DATE	DESCRIPTION

REVISIONS

DSS FILE No. 03SQ 23440-5-9249

THE ASSESSMENT, EVALUATION AND VALIDATION OF
A COMPUTER BASED SIMULATION MODEL

KRUPP TEST CASES

MONENCO LIMITED

1986-08-20 DATE	DSS	8291-8 WORK ORDER	003978 SUBCODE	017 STATUS	FIGURE 4-5

2.5Q 60%